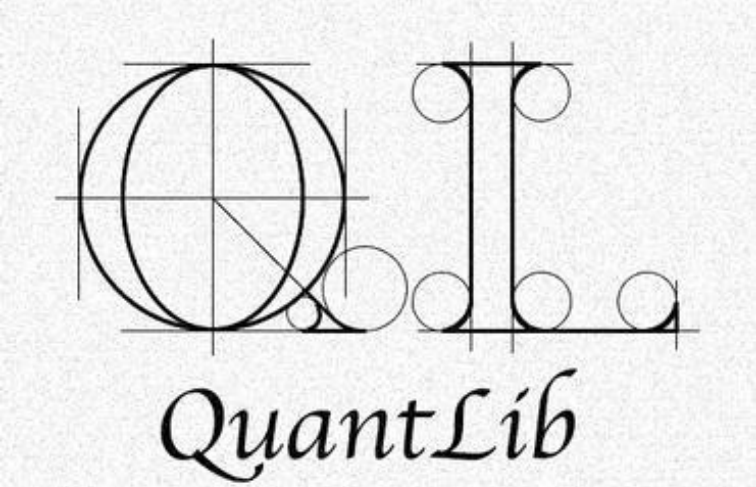

An open source library for quantitative finance

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Part I

User Manual

Chapter 1

An introduction to QuantLib

1.1 Introduction

QuantLib (http://quantlib.org/) is a C++ library for financial quantitative analysts and developers.

QuantLib is Non-Copylefted Free Software released under the modified BSD License. It is also OSI Certified Open Source Software. OSI Certified is a certification mark of the Open Source Initiative.

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1.1.1 Disclaimer

At this time, this documentation is widely incomplete and must be regarded as a work in progress. Eventually, all QuantLib classes will be documented. However, no date is currently set for this goal. Join the mailing lists (http://quantlib.org/mailinglists.html) for the latest updates.

1.2 Project overview

The QuantLib project is at this time in *beta* status.

The following list is an overview of the goals set for release 1.0. It is open for suggestions, corrections, and additions which can be submitted through the `QuantLib-users` mailing list. Every proposal will be seriously considered.

1.2.1 Project goals

Interfaces

- yield term structure—done;
- financial instrument—done;
- deal—to do;
- folder/portfolio/book levels of deal aggregation (strict vertical inclusion)—to do;
- trade-group deal aggregation (horizontal cross section)—to do;
- volatility term structure for cap/floor and swaption—to do;

Generic Tools

- date/time module—done;
- one-dimensional solver—done;
- one-dimensional optimizer—to do;
- multi-dimensional solver—to do;
- multi-dimensional optimizer—in progress;
- linear algebra module—in progress;
- statistical module—in progress;
- PDE framework—in progress;
- Monte Carlo framework—in progress;

Financial Tools

- Black-Scholes analytic implementation—done;
- Black-Scholes PDE implementation (for American and exotic options)—done;
- Deposits, FRA, futures, swaps—partly done;
- Deposit/FRA/futures/swap yield term structure—partly done;
- Swaptions—in progress;
- Caps/floors—in progress;
- Bonds (IRR/duration)—to do;
- Treasury yield term structure (Nelson-Siegel/Vasichek-Fong)—to do;
- Short-rate models (BDT, BK, HW, etc.)—in progress.

1.3 Where to get QuantLib

1.3.1 QuantLib releases

Source code, documentation, modules, etc. of current and previous QuantLib releases can be downloaded from http://quantlib.org/download.html

Debian package is available from http://ftp.us.debian.org/debian/pool/main/q/quantlib (the .us can be replaced by .jp, .uk, .de, .it, etc.)

1.3.2 Current CVS snapshot

Instructions for anonymous CVS access are available at http://quantlib.org/cvs.html

Access to the CVS repository is intended mainly for developers and is not recommended to end users which should download the latest stable release instead.

1.4 Installation

1.4.1 Linux/Unix

The simplest way to compile and install QuantLib is:

1. get the sources from
   http://quantlib.org/download.html and untar them.
2. 'cd' to the QuantLib directory and type './configure' to configure the package for your system. If you're using 'csh' on an old version of System V, you might need to type 'sh ./configure' instead to prevent 'csh' from trying to execute 'configure' itself. Running 'configure' takes awhile. While running, it prints some messages telling which features it is checking for.
3. Type 'make' to compile the package.
4. Type 'make install' to install the programs and any data files and documentation.
5. You can remove the program binaries and object files from the source code directory by typing 'make clean'. To also remove the files that 'configure' created (so you can compile the package for a different kind of computer), type 'make distclean'. There is also a 'make maintainer-clean' target, but that is intended mainly for the package's developers. If you use it, you will need some GNU tools that usually only developers use, and which are not required to build QuantLib from tarballs. These are automake, autoconf, libtool, GNU m4, GNU make, and maybe others. They all come with recent GNU/Linux distributions. To begin the build process after 'make distclean' start with 'sh ./bootstrap' which will prepare the package for compilation. You can then use 'configure' and 'make' in the usual way.

The file INSTALL.txt in the QuantLib source distribution contains more detailed instructions.

1.4.2 Win32

Binary installers are available at

http://quantlib.org/download.html

Visual C++ 6.0 projects files and Borland C++ makefiles are supplied in case one wants to rebuild the library.

The free Borland C++ compiler is available at

http://www.borland.com/bcppbuilder/freecompiler/

1.4.3 Macintosh

Codewarrior support is currently broken. QuantLib should compile under Mac OS X as outlined under Linux/Unix.

1.5 Usage

To use QuantLib classes in your own code just add

```
#include <ql/quantlib.hpp>
```

at the beginning of your source/header files.

Under the Examples folder you can find examples of QuantLib usage, including makefiles for gcc, Borland Free compiler, and Microsoft Visual C++. For the latter project files are also available.

1.5.1 Microsoft Visual C++

A few suggestions for Visual C++ users wanting to use QuantLib into their own application:

1. As long as you include ql/quantlib.hpp, you won't have to explicitly link your application to QuantLib.lib (or QuantLib_d.lib). This is automatically done by quantlib.hpp using the pragma statement:

   ```
   #ifdef _DEBUG
       #pragma comment(lib,"QuantLib_d.lib")
   #else
       #pragma comment(lib,"QuantLib.lib")
   #endif
   ```

2. Your main() must be compiled with the same options that were used in compiling the QuantLib library - namely, you'll have to set the run-time library to "Multithreaded DLL" or "Debug Multithreaded DLL" depending on whether you're linking to QuantLib.lib or QuantLib_d.lib, respectively. This setting is in the project settings, "C/C++" tab, "Code Generation" category. You'll have to check the "Use RTTI" option under the "C++ Language" category, too. Finally, you have to define NOMINMAX

3. To create your own project, add it to a new or existing Workspace. Under File | New | Projects select "Win32 Console Application" (or equivalent). Under Project | Settings select your project. Select settings for: "All configuration". On the "C/C++" tab select "Preprocessor" and under "Additional include directory" add "$(QL_DIR)". This will add your current QuantLib installation directory to the include path. On the "Link" tab select "Input" and under "Additional library path" add "$(QL_DIR)\lib\Win32\VisualStudio\". This will add your current QuantLib installation directory to the library path.

4. To compile in "Win32 Debug" configuration you will need the QuantLib debug libraries, available for download from http://quantlib.org/download.html

5. The "Win32 OnTheEdgeRelease" and "Win32 OnTheEdgeDebug" configurations are equivalent to "Win32 Release" and "Win32 Debug" respectively, except that they do not use the installed QuantLib libraries, but look for the hpp and lib QuantLib files in a relative ..\QuantLib path. This is mainly for QuantLib developers, to allow them to check the examples without having to install their unstable working version of QuantLib. The "OnTheEdge" approach may be adopted in projects using QuantLib, allowing for a quick and easy way to check how the projects work with a new QuantLib release without having to install it.

1.6 Supported platforms

The following is a list of configurations and compilers supported by QuantLib. All configuration names may have up to four parts: cpu-manufacturer-kernel-operating_system.

There are 3 officially supported configuration/compiler couples:

CONFIGURATION	COMPILER	COORDINATOR
i686-pc-linux-debian2.2	gcc 2.95 and 3.0.1	Enrico Sirola
i686-pc-WinNT4	MS Visual C++ 6	Ferdinando Ametrano
i686-pc-WinNT4	Borland free compiler	Luigi Ballabio

Dirk Eddelbuettel is the maintainer of the QuantLib Debian packages. QuantLib was reported to compile also under:

CONFIGURATION	COMPILER
i686-pc-cygwin	gcc 2.95.2
alpha-RedHat6.2	Compaq 6.3.9.3
FreeBSD	gcc 2.95.2
sparc-sun-solaris	gcc 2.95.2
sparc-sun-linux-debian	gcc 2.95.2
sgi-linux	gcc 2.95
ppc-linux	gcc 2.95.2
arm	
ia64	
m68k	
s390	

For all these platforms Debian packages are available. If you compiled (or failed to compile) QuantLib on different configurations and/or compilers please report your feedback to: quantlib-users@lists.sourceforge.net

1.7 Version history

Release 0.2.1 - December 3rd, 2001

MONTE CARLO FRAMEWORK

- Path and MultiPath are now classes on their own
- PathPricer now handles both Path and MultiPath
- MonteCarloModel now handles both single factor and multi factors simulations.
- McPricer now handles both single factor and multi factors pricing. New pricing interface
- antithetic variance-reduction technique made possible in Monte Carlo for both single factor and multi factors
- Control Variate specific class removed: control variation technique is now handled by the general MC model
- average price and average strike asian option refactored
- Sample as a (value,weight) struct
- random number generators moved under RandomNumbers folder and namespace

FINITE DIFFERENCE FRAMEWORK

- BackwardEuler and ForwardEuler renamed ImplicitEuler and ExplicitEuler, respectively
- refactoring of TridiagonalOperator and derived classes

YIELD TERM STRUCTURE AND FIXED INCOME

- Added some useful methods to term structure classes
- Allowed passing a quote to RateHelpers as double
- added FuturesRateHelpers (no convexity adjustment yet)
- PiecewiseFlatForward now observer of rates passed as MarketElements
- Unified Date and Time interface in TermStructure
- Added BPS to generic swap legs
- added term_structure+swap example
- Fixing days introduced for floating-coupon bond

PATTERNS

- Added factory pattern
- Calendar and DayCounter now use the Strategy pattern

VARIOUS

- used do-while-false idiom in QL_REQUIRE-like macros
- now using size_t where appropriate
- dividendYield is now a Spread instead of a Rate (that is: cost of carry is allowed)
- RelinkableHandle initialized with an optional Handle
- Worked around VC++ problems in History constructor
- added QL_VERSION and QL_HEX_VERSION
- generic bug fixes
- removed classes deprecated in 0.2.0

INSTALLATION FACILITIES

- improved and smoother Win32 binary installer

DOCUMENTATION

- general re-hauling
- improved and extended Monte Carlo documentation
- improved and extended examples
- Upgraded to Doxygen 1.2.11.1
- Added man pages for installed executables
- added docs in Windows Help format
- added info on ”Win32 OnTheEdgeRelease” and ”Win32 OnTheEdgeDebug” MS VC++ configurations
- additional information on how to create a MS VC++ project based on QuantLib

Release 0.2.0 - September 18th, 2001

- Library:
  - source code moved under ql, better GNU standards
  - gcc build dir can now be separated from source tree
  - gcc 3.0.1 port
  - clean compilation (no warnings)
  - bootstrap script on cygwin
  - Fixed automatic choice of seed for random number generators
  - Actual/actual classes
  - extended platform support (see table in documentation)
  - antithetic variance-reduction technique made possible in Monte Carlo
  - added dividend-Rho greek
  - First implementation of segment integral (to be redesigned)
  - Knuth random generator
  - Cash flows, scheduler, and swap (both generic and simple) added
  - added ICGaussian random generator
  - generic bug fixes
- Installation facilities:
  - improved and smoother Win32 binary installer
  - better distribution
  - debian packages available
- Documentation:
  - general re-hauling
  - added examples of using QuantLib and of projects based on QL

Release 0.1.9 - May 31st, 2001

- Library:
  - Style guidelines introduced (see `http://quantlib.org/style.html`) and partially enforced
  - full support for Microsoft Visual Studio
  - full support for Linux/gcc
  - momentarily broken support for Metrowerks CodeWarrior
  - autoconfiscation (with specialized config.∗.hpp files for platforms without automake/autoconf support)
  - Include files moved under Include/ql folder and referenced as ”ql/header.hpp”

  - Implemented expression templates techniques for array algebra optimization
  - Added custom iterators
  - Improved term structure
  - Added Asian, Bermudan, Shout, Cliquet, Himalaya, and Barrier options (all with greeks calculation, control variated where possible)
  - Added Helsinki and Wellington calendars
  - Improved Normal distribution related functions: cumulative, inverse cumulative, etc.
  - Added uniform and Gaussian random number generators
  - Added Statistics class (mean, variance, skewness, downside variance, etc.)
  - Added RiskMeasures class: VAR, average shortfall, expected shortfall, etc.
  - Added RiskStatistics class combining Statistics and RiskMeasures
  - Added sample accumulator for multivariate analysis
  - Added Monte Carlo tools
  - Added matrix-related functions (square root, symmetric Schur decomposition)
  - Added interpolation framework (linear and cubic spline interpolation implemented).

- Installation facilities:

  - Added Win32 GUI installer for binaries

- Documentation:

  - support for Doxygen 1.2.7
  - Added man documentation

Release 0.1.1 - November 21st, 2000

Initial release.

1.8 Todo List

Class QuantLib::Volatilities::CapFlatVolatilityVector Either add correct copy behavior or inhibit copy. Right now, a copied instance would end up with its own copy of the length vector but an interpolation pointing to the original ones.

Class QuantLib::Pricers::ContinuousGeometricAPO add Average Strike version and make it backward starting

Class QuantLib::Pricers::DiscreteGeometricAPO add analytical greeks

Class QuantLib::Pricers::DiscreteGeometricASO add analytical greeks

Class QuantLib::FiniteDifferences::ExplicitEuler add Richardson extrapolation

Class QuantLib::Pricers::FdAmericanOption make american call with no dividens = european

Class QuantLib::CashFlows::FloatingRateCouponVector A suitable algorithm should be implemented for the calculation of the interpolated index fixing for a short/long first coupon.

Class QuantLib::TermStructures::FraRateHelper convexity adjustment should be implemented.

Class QuantLib::Math::Interpolation2D Bicubic interpolation and bicubic spline

Class QuantLib::Pricers::McDiscreteArithmeticAPO Continous Averaging version

Class QuantLib::Pricers::McDiscreteArithmeticASO Continous Averaging version

Class QuantLib::FiniteDifferences::MixedScheme add Douglas Scheme

Class QuantLib::MonteCarlo::MultiPath make it time-aware

Class QuantLib::MonteCarlo::Path make it time-aware

Class QuantLib::MonteCarlo::PathGenerator add more general path generator with drift(S,t) and variance(S,t)

Class QuantLib::Math::SegmentIntegral Redesign as a template function.

Class QuantLib::Volatilities::SwaptionVolatilityMatrix Either add correct copy behavior or inhibit copy. Right now, a copied instance would end up with its own copy of the exercise date and length vector but an interpolation pointing to the original ones.

Class QuantLib::Calendars::Tokyo insert actual rules for Equinoxes

1.9 Additional resources

The main QuantLib resource is the QuantLib site (http://quantlib.org).

Additional resources available from the above site include:

- current news;
- the QuantLib mailing lists (http://quantlib.org/mailinglists.html);
- the QuantLib FAQ (http://quantlib.org/FAQ.html);
- the QuantLib programming style guidelines (http://quantlib.org/style.html);
- a link to the QuantLib project page on Sourceforge.net;
- links to pages for bug reports, patch submissions and feature requests;
- a page (http://quantlib.org/extensions.html) about how to use QuantLib in other languages/platforms;
- as well as links to additional quantitative finance resources.

1.10 The QuantLib Group

1.10.1 Authors

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1.10.2 Contributors

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1.11 Copyright and License

1.11.1 Comments on Copyright and License

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QuantLib is Open Source [3] because of its license: it is OSI Certified Open Source Software [4]. OSI Certified is a certification mark of the Open Source Initiative [5].

The modified BSD License is GPL compatible as confirmed by the Free Software Foundation [6].

This license has been adopted to allow free use of QuantLib and its source, to make QuantLib flourish as a free-software/open-source project. It allows proprietary extensions to be commercialized.

[1] http://www.gnu.org/philosophy/categories.html#Non-CopyleftedFree-Software

[2] http://www.opensource.org/licenses/bsd-license.html

[3] http://www.opensource.org/docs/definition.html

[4] http://www.opensource.org/docs/certification_mark.html

[5] http://www.opensource.org

[6] http://www.gnu.org/philosophy/bsd.html

Chapter 2

QuantLib components

2.1 Core classes

Documentation for this part of the library is in progress.

The root namespace QuantLib contains what can be considered the QuantLib foundation, i.e., the core of abstract classes upon which the rest of the library is built.

The folder structure of the sources reflects the organization of classes and functions into namespaces. These are in turn chosen to represent definite *packages* or *class families*: the former being groups of classes forming a framework for particular applications, e.g., the PDE package for partial differential equations; and the latter being sets of classes which inherit from a common base class or otherwise share a common functionality and interface, e.g., the TermStructures or Operators families, respectively.

In the QuantLib namespace:

- A number of financial types is provided, such as QuantLib::Rate, QuantLib::Spread, or QuantLib::DiscountFactor. All these types act as, and indeed are, doubles.
- The Date, Calendar and DayCounter classes are defined (see Date and time calculations).
- The abstract classes QuantLib::ForwardVolatilitySurface and QuantLib::SwaptionVolatilitySurface provide the common interface to concrete volatility models. No examples are available at this time, and the classes themselves will probably need some reworking.
- The abstract class QuantLib::Solver1D provides a common interface for the one-dimensional solvers implemented in the QuantLib::Solvers1D namespace.
- The abstract class QuantLib::Index provides the common interface of the classes implemented in the QuantLib::Indexes namespace.
- The abstract class QuantLib::Instrument provides a common interface and a calculation ramework for the classes implemented in the QuantLib::Instruments namespace.
- The abstract class QuantLib::TermStructure provides a common interface for the classes implemented in the QuantLib::TermStructures namespace.

2.2 Date and time calculations

Documentation for this part of the library is in progress.

2.2.1 Dates

The concrete class QuantLib::Date implements the concept of date. Its functionalities include:

- providing basic information such as weekday, day of the month, day of the year, month, and year;
- comparing two dates to determine whether they are equal, or which one is the earlier or later, or the difference between them expressed in days;
- incrementing or decrementing a date of a given number of days, or of a given period expressed in weeks, months, or years.

2.2.2 Calendars

The abstract class QuantLib::Calendar provides the interface for determining whether a date is a business day or a holiday for a given market, or incrementing/decrementing a date of a given number of business days. A number of calendars is contained in the QuantLib::Calendars namespace, namely,

- Frankfurt
- Helsinki
- London
- Milan
- NewYork
- TARGET
- Wellington
- Zurich

2.2.3 Day counters

The abstract class QuantLib::DayCounter provides more advanced means of measuring the distance between two dates according to a given market convention, both as number of days of fraction of year. A number of such conventions is contained in the QuantLib::DayCounters namespace, namely,

- Actual/360
- Actual/365
- Actual/Actual, which can be calculated according to:
  - ISMA and US Treasury convention, also known as ”Actual/Actual (Bond)”;
  - ISDA, also known as ”Actual/Actual (Historical)”;
  - AFB, also known as ”Actual/Actual (Euro)”;
- 30/360, which can be calculated according to:
  - USA convention;
  - European convention;
  - Italian convention.

2.3 The finite differences framework

This framework (corresponding to the QuantLib::FiniteDifferences namespace) contains basic building blocks for the numerical solution of a generic differential equation

$$\frac{\partial f}{\partial t} = Lf$$

where L is a differential operator in "space", i.e., one which does not contain partial derivatives in t but can otherwise contain any derivative in any other variable of the problem.

Writing the equation in the above form allows us to implement separately the discretization of the differential operator L and the time scheme used for the evolution of the solution. The QuantLib::FiniteDifferences::FiniteDifferenceModel class acts as a glue for such two steps—which are outlined in the following subsections—and provides the interface of the resulting finite difference model for the end user. Furthermore, it provides the possibility of checking and operating on the solution array at each step—which is typically used to apply an exercise condition for an option. This is also outlined in a subsection below.

2.3.1 Differential operators

The discretization of the differential operator L depends on the discretization chosen for the solution f of the given equation.

Such choice is obvious in the 1-D case where the domain $[a,b]$ of the equation is discretized as a series of points $x_i, i = 0 \ldots N-1$ (note that the index is zero based) where $x_i = a+hi$ and $h = (b-a)/(N-1)$. In turn, the solution f of the equation is discretized as an array $u_i, i = 0 \ldots N-1$ whose elements are defined as $u_i = f(x_i)$. The discretization of the differential operator follows by substituting the derivatives with the corresponding incremental ratios defined in terms of the f_i. A number of basic operators are defined in the framework which can be composed to form more complex operators, namely:

the identity operator I is implemented in class Identity;

the first derivative $\partial/\partial x$ is discretized as the operator D_+, defined as

$$D_+ u_i = \frac{u_{i+1} - u_i}{h}$$

and implemented in class QuantLib::FiniteDifferences::DPlus; the operator D_-, defined as

$$D_- u_i = \frac{u_i - u_{i-1}}{h}$$

and implemented in class QuantLib::FiniteDifferences::DMinus; and the operator D_0, defined as

$$D_0 u_i = \frac{u_{i+1} - u_{i-1}}{2h}$$

and implemented in class QuantLib::FiniteDifferences::DZero. The discretization error of the above operators is $O(h)$ for D_+ and D_- and $O(h^2)$ for D_0;

the second derivative $\partial^2/\partial x^2$ is discretized as the operator D_+D_-, defined as

$$D_+ D_- u_i = \frac{u_{i+1} - 2u_i + u_{i-1}}{h^2}$$

and implemented in class QuantLib::FiniteDifferences::DPlusDMinus. Its discretization error is $O(h^2)$.

The boundary condition for the above operators is by default linear extrapolation. Methods are currently provided for setting other kinds of boundary conditions to a tridiagonal operator which these operators inherit, namely, Dirichlet—i.e., constant value—and Neumann—i.e., constant derivative—boundary conditions. This might change in the future as boundary conditions could be astracted and passed as an additional argument to the model.

A programmer can also implement its own operator. However, in order to fit into this framework it will have to implement a required interface depending on the chosen evolver (see below). Also, it is currently required to manage itself any boundary conditions. Again, this could change in the future.

On the other hand, there is no obvious choice in the 2-D case. While it is immediate to discretize the domain into a series of points (x_i, y_j) and the solution into a matrix $f_{ij} = f(x_i, y_j)$, there is a number of ways into which the f_{ij} can be arranged into an array—each of them determining a different discretization of the differential operators. One of such ways was implemented in the LexicographicalView class, while others will be implemented in the future. No 2-D operator is currently implemented apart from the identity operator.

2.3.2 Time schemes

Once the differential operator L has been discretized, a number of choices are available for discretizing the time derivative at the left-hand side of the equation.

In this framework, such choice is encapsulated in so-called evolvers which, given L and the solution $u^{(k)}$ at time t_k, yield the solution $u^{(k-1)}$ at the previous time step.

A number of evolvers are currently provided in the library which implement well-known schemes, namely,

the forward Euler explicit scheme in which the equation is discretized as

$$\frac{u^{(k)} - u^{(k-1)}}{\Delta t} = Lu^{(k)}$$

hence

$$u^{(k-1)} = (I - \Delta t L)\, u^{(k)}$$

from which $u^{(k-1)}$ can be obtained directly;

the backward Euler implicit scheme in which the equation is discretized as

$$\frac{u^{(k)} - u^{(k-1)}}{\Delta t} = Lu^{(k-1)}$$

hence

$$(I + \Delta t L)\, u^{(k-1)} = u^{(k)}$$

from which $u^{(k-1)}$ can be obtained by solving a linear system;

the Crank-Nicolson scheme in which the equation is discretized as

$$\frac{u^{(k)} - u^{(k-1)}}{\Delta t} = L\frac{u^{(k)} + u^{(k-1)}}{2}$$

hence

$$\left(I + \frac{\Delta t}{2} L\right) u^{(k-1)} = \left(I - \frac{\Delta t}{2} L\right) u^{(k)}$$

from which $u^{(k-1)}$ can be obtained by solving a linear system.

Each of the above evolvers forces a set of interface requirements upon the differential operator which are detailed in the documentation of the corresponding class, namely, QuantLib::FiniteDifferences::Explicit-Euler, QuantLib::FiniteDifferences::ImplicitEuler, and QuantLib::FiniteDifferences::CrankNicolson, respectively.

A programmer could implement its own evolver, which does not need to inherit from any base class.

However, it must implement the following interface:

```
class Evolver {
  public:
    typedef ... arrayType;
    typedef ... operatorType;
    // constructors
    Evolver(const operatorType& D);
    // member functions
    void step(arrayType& a, Time t) const;
    void setStep(Time dt);
};
```

Finally, we note again that the pricing of an option requires the finite difference model to solve the corresponding equation *backwards* in time. Therefore, given a discretization u of the solution at a given time t, the call

```
evolver.step(u,t)
```

must calculate the discrete solution at the *previous* time, $t - dt$.

2.3.3 Step conditions

A finite difference model can be passed a step condition to be applied at each step during the rollback of the solution (e.g. the early exercise American condition). Such condition must be embodied in a class derived from QuantLib::FiniteDifferences::StepCondition and must implement the interface of the latter, namely,

```
class MyCondition : public StepCondition<arrayType> {
  public:
    void applyTo(arrayType& a, Time t) const;
};
```

2.3.4 An example of finite difference model

The Black-Scholes equation can be written in the above form as

$$\frac{\partial f}{\partial t} = -\frac{\sigma^2}{2}\frac{\partial^2 f}{\partial x^2} - \nu\frac{\partial f}{\partial x} + rf.$$

It can be seen that the operator L_{BS} is

$$L_{BS} = -\frac{\sigma^2}{2}\frac{\partial^2}{\partial x^2} - \nu\frac{\partial}{\partial x} + rI$$

and can be built from the basic operators provided in the library as

$$L_{BS} = -\frac{\sigma^2}{2}D_+D_- - \nu D_0 + rI.$$

Its implementation closely reflects the above decomposition and can be written as

```
class BlackScholesOperator : public TridiagonalOperator {
  public:
    BlackScholesOperator(
        double sigma, double nu,    // parameters of the
        Rate r,                     // Black-Scholes equation;
        unsigned int points,        // number of discretized points;
        double h)                   // grid spacing.
```

```
    : TridiagonalOperator(
        // build the operator by adding basic ones
        - (sigma*sigma/2.0) * DPlusDMinus(points,h)
        - nu * DZero(points,h)
        + r * TridiagonalOperator::identity(points)
    ) {}
};
```

taking as inputs the relevant parameters of the equation (σ, ν and r) as well as model parameters such as the number N of grid points and their spacing h.

As simple example cases, we will use the above operator to price both an European and an American option. The parameters of the two options will be the same, namely, they will be both call options with underlying price $u = 100$, strike $s = 95$, residual time $T = 1$ year, dividend yield $q = 3\%$ and volatility $\sigma = 10\%$. The risk-free rate will be $r = 5\%$. Such parameters are expressed using QuantLib types as

```
Option::Type type = Option::Call;
double underlying = 100.0, strike = 95.0;
Time residualTime = 1.0;
Rate dividendYield = 0.03, riskFreeRate = 0.05;
double volatility = 0.10;
```

The grid upon which the model will act will be a logarithmic grid of underlying prices, i.e., f will be defined in a range $[\ln u_{min}, \ln u_{max}]$ discretized as an array $x_i, i = 0 \ldots N-1$ with $x_i = \ln u_{min} + ih$ and $h = (\ln u_{max} - \ln u_{min})/(N-1)$. Such a grid and the corresponding vector of actual prices can be built as shown in the code below. The domain of the model will be defined as $[\ln u - \Delta, \ln u + \Delta]$ where $\Delta = 4\sigma\sqrt{T}$. A number of grid points $N = 101$ will be used.

```
unsigned int gridPoints = 101;
Array grid(gridPoints), prices(gridPoints);
double x0 = QL_LOG(underlying);
double Delta = 4.0*volatility*QL_SQRT(residualTime);
double xMin = x0 - Delta, xMax = x0 + Delta;
double h = (xMax-xMin)/(gridPoints-1);
for (unsigned int i=0; i<gridPoints; i++) {
    grid[i] = xMin + i*h;
    prices[i] = QL_EXP(grid[i]);
}
```

The initial condition is determined by the values of the option at maturity, i.e., either the difference between underlying price and strike if such difference is positive, or 0 if that is not the case (the above will have to be suitably modified for a put option or a straddle.) Such "initial" condition will be rolled back in time by our model.

```
Array exercisingValue(gridPoints);
for (unsigned int i=0; i<gridPoints; i++)
    exercisingValue[i] = QL_MAX(prices[i]-strike,0.0);
```

Now the differential operator can be initialized. Also, Neumann initial conditions are set which correspond to the initial value of the derivatives at the boundaries (see the BoundaryCondition class documentation for details).

```
double nu = riskFreeRate - dividendYield - volatility*volatility/2.0;
TridiagonalOperator L = BlackScholesOperator(volatility, nu,
    riskFreeRate, gridPoints, h);
L.setLowerBC(BoundaryCondition(BoundaryCondition::Neumann,
    exercisingValue[1]-exercisingValue[0]));
L.setUpperBC(BoundaryCondition(BoundaryCondition::Neumann,
    exercisingValue[gridPoints_-1]-exercisingValue[gridPoints_-2]));
```

We are now already set for the pricing of the European option. Also, the exercise condition is the only thing still to be defined for the American option to be priced. Such condition is equivalent to the statement that at each time step, the value of the option is the maximum between the profit realized in exercising the option (which we already calculated and stored in `exercisingValue`) and the value of the option should we keep it (which corresponds to the solution rolled back to the current time step). This logic can be implemented as:

```
class ExerciseCondition : public StepCondition<Array> {
  public:
    ExerciseCondition(const Array& exercisingValue)
    : exercisingValue_(exercisingValue) {}
    void applyTo(Array& a, Time) const {
        for (unsigned int i = 0; i < a.size(); i++)
            a[i] = QL_MAX(a[i], exercisingValue_[i]);
    }
  private:
    Array exercisingValue_;
};
```

Everything is now ready. The model can be created gluing the piece together by means of the QuantLib::FiniteDifferences::FiniteDifferenceModel class. The current value of the option is calculated by rolling back the solution to the current time, i.e., $t = 0$, and by taking the value corresponding at the current underlying price—which by construction corresponds to the central value provided that the number of grid points is odd.

```
unsigned int timeSteps = 365;

// build the model - Crank-Nicolson scheme chosen
FiniteDifferenceModel<CrankNicolson<TridiagonalOperator> > model(L);

// European option
Array f = exercisingValue;  // initial condition
model.rollback(f, residualTime, 0.0, timeSteps);
double europeanValue = valueAtCenter(f);

// American option
f = exercisingValue;        // reset
Handle<StepCondition<Array> > condition(
    new ExerciseCondition(exercisingValue));
model.rollback(f, residualTime, 0.0, timeSteps, condition);
double americanValue = valueAtCenter(f);
```

2.4 The Monte Carlo framework

> Anyone attempting to generate random numbers by deterministic means is, of course, living in a state of sin. — John Von Neumann

This framework (corresponding to the QuantLib::MonteCarlo namespace) contains basic building blocks for the numerical calculation of the integral

$$\int_{\Omega} f(\mathbf{x})p(\mathbf{x})d\mathbf{x}$$

where $p(\mathbf{x})$ is a normalized probability function. Monte Carlo methods solve the above integral by approximating it with the discrete sum

$$\frac{1}{N}\sum_{i=1}^{N} f(\mathbf{x}_i)w(\mathbf{x}_i)$$

where the $\mathbf{x}_i$ are drawn from $p(\mathbf{x})$, possibly with a weight $w(\mathbf{x}_i)$—which otherwise can be considered uniformly equal to 1.

The above sum has a straightforward interpretation in the case of a derivative product, namely, the $\mathbf{x}_i$ are N generated random paths which the value of the underlying can possibly follow, while the $f(\mathbf{x}_i)$ are the values of the derivative on each of such paths. The sum above can therefore be taken as an estimate of the price of the derivative, namely, the average of its value on all possible paths—or rather all considered paths. Such a method enables the user to construct pricing classes for an unlimited range of derivatives, most notably path-dependent ones which cannot be priced by means of finite difference methods.

It must also be mentioned that for all such methods, the error e on the estimated value is proportional to the square root of the number of samples N. A number of so-called *variance-reduction* methods have been found which allows one to reduce the coefficient of proportionality between e and $1/\sqrt{N}$.

Separate implementations are provided in the library for the three components of the above average, namely, the random drawing of the $\mathbf{x}_i$, the evaluation of the $f(\mathbf{x}_i)$, and the averaging process itself. The QuantLib::MonteCarlo::MonteCarloModel class acts as a glue for such three steps—which are outlined in the following subsections—and provides the interface of the resulting Monte Carlo model to the end user.

2.4.1 Path generation

The Black-Scholes equation

$$\frac{\partial t}{\partial t} + \frac{\sigma^2}{2}\frac{\partial^2 f}{\partial x^2} + \nu\frac{\partial f}{\partial x} - rf = 0,$$

where r is the risk-free rate, σ is the volatility of the underlying, and $\nu = r - \sigma^2/2$, has the form of a diffusion process. According to this heuristic interpretation (1), paths followed by the logarithm of the underlying would be Brownian random walks with a constant drift ν per unit time and a standard deviation $\sigma\sqrt{T}$ over a time T.

Therefore, the paths to be generated for a Monte Carlo model of the Black-Scholes equation will be vectors of successive variations of the logarithm of the underlying price over N consecutive time intervals $\Delta t_i, i = 0 \ldots N-1$. Each such variation will be drawn from a Gaussian distribution with average $\nu\Delta T_i$ and standard deviation $\sigma\sqrt{\Delta T_i}$—or possibly $\nu_i\Delta T_i$ and $\sigma_i\sqrt{\Delta T_i}$ should ν and σ vary in time.

The QuantLib::MonteCarlo::Path class stores the variation vector decomposed in its drift (determined) and diffusion (random) components. As shown below, this allows the implementation of antithetic variance reduction techniques.

The QuantLib::MonteCarlo::MultiPath class is a straightforward extension which acts as a vector of Path objects.

Classes are provided which generate paths and multi-paths with the desired drift and diffusion components, namely, QuantLib::MonteCarlo::PathGenerator and QuantLib::MonteCarlo::MultiPathGenerator.

For the time being, the path generator is initialized with a constant drift and variance. This requirement will most likely be relaxed in the next release. The multi-path generator is initialized with an array of constant drifts—one for each single path—and a covariance matrix which encapsulates the relations between the diffusion components of the single paths.

The time discretization of the (multi)paths can be specifies either as a given number of equal time steps over a given time span, or as a vector of explicitly specified times at which the path will be sampled.

2.4.2 Pricing an instrument on a path

The QuantLib::MonteCarlo::PathPricer class is the base class from which path pricers must inherit. The only method which subclasses are required to implement is

```
double operator()(const P&) const;
```

where P can be Path or MultiPath depending on the derivative whose value must be calculated.

Similarly, the term *path* will be used in the following discussion as meaning either path or multi-path depending on the context. The term *single path* is not to be taken as opposite to multi-path, but rather as meaning "a single instance of a (multi)path" as opposed to the set of all generated (multi)paths.

The above method encapsulates the pricing of the derivative on a single path and must return its value had the evolution of the underlying(s) followed the path passed as argument. For this reason, control variate techniques (see below) must not be implemented at this level since they would cause the returned value to differ from the actual price of the derivative on the path.

Instead, antithetic variance-reduction techniques can be effectively implemented at this level and indeed are used in the pricers currently included in the library.

In short, such techniques consist in pricing an option on both the given path and its antithetic, the latter being a path with the same drift and the opposite diffusion component. The value of the sample is defined as the average of the prices on the two paths.

A generic implementation of antithetic techniques could consist of a path pricer class which takes a concrete path pricer upon construction and whose operator() simply proxies two calls to the contained pricer, passing the given path and its antithetic, and averages the result. However, this would not take full advantage of the technique.

In fact, it must be noted that using antithetic paths not only reduces the variance *per se* but also allows to factor out calculations commons to a path and its antithetic, thus reducing greatly the computation time. Therefore, such techniques are best implemented inside the path pricer itself, whose algorithm can fully exploit such factorization.

A number of path pricers are available in the library and are listed in the QuantLib::MonteCarlo namespace reference.

2.4.3 Accumulating and averaging samples

The class QuantLib::MonteCarlo::MonteCarloModel encapsulates the general structure of a Monte Carlo calculations, namely, the generation of a number of paths, the pricing of the derivative on each path, and the averaging of the results to yield the actual derivative price.

As outlined above, the first two steps are delegated to a path generator and a path pricer. The third step is also delegated to an object which accumulates weighted values and returns the statistic properties of the set of such values. One such class provided by the library is QuantLib::Math::Statistics.

The concern of the Monte Carlo model is therefore to act as a glue between such three components and can be expressed by the following pseudo-code:

```
given pathGenerator, pathPricer, accumulator;
for i in number of samples {
    path,weight  = pathGenerator.next();
    price = pathPricer(path);
    accumulator.add(price,weight);
}
```

The Monte Carlo model also provides the user with the possibility to take advantage of control-variate techniques.

Such techniques consist in pricing a portfolio from which the price of the derivative can be deduced, but with a lower variance than the derivative alone.

In our current implementation, static-hedge control variate is used, namely, the formed portfolio is long of the derivative we need to price and short of a similar derivative whose price can be calculated analytically. The value of the portfolio on a given path will of course be given by the difference of the values of the two derivatives on such path. However, due to the similarity between the derivatives, the portfolio price will have a lower variance than either derivative alone since any variation in the price of the latter will be partly compensated by a similar variation in the price of the other. Lastly, given the portfolio price, the price of the derivative we are interested in can be deduced by adding the analytic value of the other.

In order to use such technique, the user must provide the model with a path pricer for the additional option and the value of the latter. The action of the Monte Carlo model is in this case expressed as:

```
given pathGenerator, pathPricer, cvPathPricer, cvPrice, accumulator;
for i in number of samples {
    path,weight  = pathGenerator.next();
    portfolioPrice = pathPricer(path) - cvPathPricer(path);
    accumulator.add(portfolioPrice+cvPrice,weight);
}
```

Martingale (a.k.a. dynamic-hedge) control variate techniques are planned for future releases.

A QuantLib::Pricers::McPricer class is also available which wraps the typical usage of a Monte Carlo model.

Details on the Monte Carlo Pricer interface will be available in the pricers section.

2.4.4 Examples of Monte Carlo models

As a simple example, we will use the outlined tools to price an European option by means of Monte Carlo techniques.

Given a current underlying price u_0 and a path $p = [p_1, \ldots, p_N]$ where every variation p_i is the sum of a drift term d_i and a random diffusion term r_i, the price of the underlying at maturity is

$$u = u_0 \prod_1^N e^{p_i} = u_0 \exp\left(\sum_1^N p_i\right) = u_0 \exp\left(\sum_1^N d_i + \sum_1^N r_i\right)$$

while the price on the antithetic path—i.e., same drift and opposite diffusion—is

$$u_0 \exp\left(\sum_1^N d_i - \sum_1^N r_i\right).$$

The corresponding path pricer can be implemented as:

```
class EuropeanPathPricer : public PathPricer<Path> {
  public:
    EuropeanPathPricer(Option::Type type, double underlying,
                       double strike, DiscountFactor discount,
                       bool useAntithetic)
    // just store the needed parameters
    : type_(type), underlying_(underlying), strike_(strike),
      discount_(discount), useAntithetic_(useAntithetic) {}
    // here is the logic
    double operator()(const Path& path) const {

        size_t n = path.size();

        // factor out the sums in the formula above
        double sum_d = 0.0, sum_r = 0.0;
        for (size_t i = 0; i < n; i++) {
            sum_d += path.drift()[i];
            sum_r += path.diffusion()[i];
        }

        // calculate final underlying price on path
        double price = underlying_*QL_EXP(sum_d+sum_r);

        // calculate payoff
        double payoff;
        switch (type_) {
          case Option::Call;
            payoff = QL_MAX(price-strike,0.0);
            break;
          // other cases are left as an exercise to the reader
          ...
        }

        // current value of the option is the discounted payoff
        double optionValue = payoff*discount_;

        // stop here if not antithetic...
        if (!useAntithetic_)
            return optionValue;

        // ...otherwise calculate the value on the antithetic path
        double antiPrice = underlying_*QL_EXP(sum_d-sum_r);

        // calculate payoff and option value as above
        ...

        // return the average of the results on the two paths
        return (optionValue + antiOptionValue)/2.0;
    }
  private:
    // stored parameters
    ...
};
```

The path pricer can now be used in a model. Let us assume the following parameters:

```
Option::Type type = Option::Call;
double underlying = 100.0, strike = 95.0;
Time residualTime = 1.0;
Rate dividendYield = 0.03, riskFreeRate = 0.05;
double volatility = 0.10;
```

The path generator can be instantiated as

```
// parameters of the Black-Scholes equation
double vol2 = volatility*volatility;
double nu = riskFreeRate - dividendYield - vol2/2.0;
// in this case we are only interested in the final underlying price.
// Therefore, we can cover all the residual time in one big time step.
int timeSteps = 1;

Handle<GaussianPathGenerator> pathGenerator(
    new GaussianPathGenerator(nu,vol2,residualTime,timeSteps));
```

where QuantLib::MonteCarlo::GaussianPathGenerator is a typedef to a path generator using the default choice for a Gaussian random number generator.

The path pricer is instantiated as

```
// discount at maturity
DiscountFactor discount = QL_EXP(-riskFreeRate*residualTime);
bool antithetic = true;

Handle<PathPricer<Path> > pathPricer(
    new EuropeanPathPricer(type,underlying,strike,discount,antithetic));
```

The model can now be created and used as following:

```
// number of samples to be generated
size_t samples = 1000000;

// pass the path generator and pricer we just created and a
// newly instantiated Statistics object
MonteCarloModel<Statistics,GaussianPathGenerator,PathPricer> model(
    pathGenerator,pathPricer,Statistics());

model.addSamples(samples);

// now get the results: the option price is given by value with
// a confidence level given by error
value = model.sampleAccumulator().mean();
error = model.sampleAccumulator().errorEstimate();
```

More examples of path pricers can be found in the QuantLib::MonteCarlo namespace, while examples of more sophisticated pricers which uses them in Monte Carlo models can be found in the QuantLib::Pricers namespace.

2.4.5 Notes

(1) A more rigorous approach would lead us to integrate the above equation by means of Green functions or Laplace transforms. Both such methods would show that the price at time $t = 0$ of an option with payoff $G(S(T))$ where $S(T)$ is the underlying price at expiry is given by the integral

$$\int_{-\infty}^{\infty} e^{-rT} G(S_0 e^{\xi}) \frac{1}{\sqrt{2\pi\sigma^2 T}} \exp\left(-\frac{(\xi - \nu T)^2}{2\sigma^2 T}\right) \mathrm{d}\xi$$

where S_0 is the price of the underlying at $t = 0$. It can be seen that the above integral is of the form shown at the beginning of this section, namely, the pricing function is

$$f(x) = e^{-rT} G(S_0 e^{x})$$

and can be interpreted as the option payoff discounted to the present time, while the probability distribution is

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2 T}} \exp\left(-\frac{(x-\nu T)^2}{2\sigma^2 T}\right).$$

which again shows that the logarithms of the underlying prices at time T are distributed as a Gaussian with average νT and standard deviation $\sigma\sqrt{T}$.

2.5 The interest rate modelling framework

This framework (corresponding to the InterestRateModelling namespace) implements some basic interest rate modelling tools, i.e. single factor short rate models. The models implemented in this library are widely used by practitionners. For the moment, the model class basically define a driving stochastic equation of the type

$$dx = \mu(t,x)dt + \sigma(t,x)dW_t$$

where $r = f(t,x)$ and define, if possible, analytical formulas for discount bonds and discount bond options (useful for calibration). Numerical pricing can be done via recombining trinomial trees implemented in the Lattices::TrinomialTree class.

2.5.1 Single-factor models

The Hull & White model

$$dr_t = (\theta(t) - \alpha(t)r_t)dt + \sigma(t)dW_t$$

When α and σ are constants, this model has analytical formulas for discount bonds and discount bond options.

The Black-Karasinski model

$$d\ln r_t = (\theta(t) - \alpha \ln r_t)dt + \sigma dW_t$$

No analytical tractability here.

The Cox-Ingersoll-Ross model

$$dr_t = (\theta(t) - kr_t)dt + \sigma\sqrt{r_t}dW_t$$

There are analytical formulas for discount bonds and discount bond options.

2.5.2 Calibration

The class CalibrationHelper is a base class that facilitates the instanciation of market instruments used for calibration. It has a method marketValue() that gives the market price using a Black formula, and a modelValue() method that gives the price according to a model

The first derived class is QuantLib::InterestRateModelling::CalibrationHelpers::CapHelper. This helper creates a vanilla cap instrument, and prices it using discount bond option formulas. If no such analytical formula is available, the pricing is done using a trinomial recombining tree.

The second derived class is QuantLib::InterestRateModelling::CalibrationHelpers::SwaptionHelper. This helper creates a swaption instrument, and prices it using the Jamshidian decomposition. If no analytical formula for discount bonds is available, the pricing is done using a trinomial recombining tree.

For the calibration itself, you must choose an optimization method that will find constant parameters such that the value:

$$V = \sqrt{\sum_{i=1}^{n} \frac{T_i - M_i}{M_i}^2}$$

, where T_i is the price given by the model and M_i is the market price, is minimized. A few optimization methods are available in the Optimization namespace, and more are on the way...

2.5.3 Pricing using finite differences

If $x = x(t, r)$ is the state variable and follows this stochastic process:

$$dx_t = \mu(t, x)dt + \sigma(t, x)dW_t$$

any european-style instrument will follow the following PDE:

$$\frac{\partial P}{\partial t} + \mu\frac{\partial P}{\partial x} + \frac{1}{2}\sigma^2\frac{\partial^2 P}{\partial x^2} = r(t, x)P$$

The adequate operator to feed a Finite Difference Model instance is defined in the QuantLib::FiniteDifferences::OneFactorOperator class.

2.5.4 Pricing using trees

Each model derived from the single-factor model class has the ability to return a trinomial tree. For yield-curve consistent models, the fitting parameter can be determined either analytically (when possible) or numerically. When a tree is built, it is then pretty straightforward to implement a pricer for any path-independant derivative. Just implement a class derived from NumericalDerivative (see QuantLib::Pricers::NumericalSwaption for example) and roll it back until the present time... Just look at QuantLib::Pricers::TreeCapFloor and QuantLib::Pricers::TreeSwaption for working pricers.

2.6 Currencies and FX rates

Documentation for this part of the library is in progress.

2.7 Instruments and pricers

Documentation for this part of the library is in progress.

This section will include documentation for classes such as QuantLib::Instrument, its derived classes in the QuantLib::Instruments namespace, and the pricing engines in the QuantLib::Pricers namespace.

2.8 Math tools

Documentation for this part of the library is in progress.

Math facilities of the library include:

2.8.1 Random number and low discrepancy sequence generators

Documentation for this part of the library is in progress.

Implementations of random number and low discrepancy sequence generators. They share the QuantLib::RandomNumbers namespace.

2.8.2 One-dimensional solvers

Documentation for this part of the library is in progress.

The abstract class QuantLib::Solver1D provides the interface for one-dimensional solvers which can find the zeroes of a given function.

A number of such solvers is contained in the QuantLib::Solvers1D namespace.

The implementation of the algorithms was inspired by ”Numerical Recipes in C”, 2nd edition, Press, Teukolsky, Vetterling, Flannery - Chapter 9

Some work is needed to resolve the ambiguity of the root finding accuracy defition: for some algorithms it is the x-accuracy, for others it is f(x)-accuracy.

2.8.3 Optimizers

The optimization framework (corresponding to the Optimization namespace) implements some multi-dimensional minimizing methods. The function to be minimized is to be derived from the QuantLib::Optimization::CostFunction base class (if the gradient is not analytically implemented, it will be computed numerically).

The simplex method
see QuantLib::Optimization::Simplex .

The conjugate gradient method
see QuantLib::Optimization::ConjugateGradient .

2.9 Design patterns

Documentation for this part of the library is in progress.

2.10 Term structures

Documentation for this part of the library is in progress.

The abstract class QuantLib::TermStructure provides the common interface to concrete term structure models. Among others, methods are declared which return instantaneous forward rate, discount factor, and zero rate at a given date. Adapter classes are provided which already implement part of the required methods, thus allowing the programmer to define only the non-redundant part. The PiecewiseConstantForwards class is provided as an example in the QuantLib::TermStructures namespace.

2.11 Utilities

Documentation for this part of the library is in progress.

Iterators are meant to build a sequence on the fly from one or more other sequences, without having to allocate place for storing it. A couple of examples: suppose we have a function which calculates the average of a sequence, and that for genericity we have implemented it as a template function which takes the beginning and the end of the sequence, so that its declaration is:

```
template <class Iterator>
typename Iterator::value_type
average(const Iterator& begin, const Iterator& end)
```

This kind of genericity allows one to use the same function to calculate the average of a std::vector, a std::list, a QuantLib::History, any other container, of a subset of any of the former.

Now let's say we have two sequences of numbers, and we want to calculate the average of their products. One approach could be to store the products in another sequence, and to calculate the average of the latter, as in:

```
// we have sequence1 and sequence2 and assume equal size:
// first we store their product in a vector...
std::vector<double> products;
std::transform(sequence1.begin(),sequence1.end(), // first sequence
               sequence2.begin(),                 // second sequence
               std::back_inserter(products),      // output
               std::multiplies<double>());        // operation to perform
// ...then we calculate the average
double result = average(products.begin(),products.end());
```

The above works, however, it might be not particularly efficient since we have to allocate the product vector, quite possibly just to throw it away when the calculation is done.

QuantLib::Utilities::coupling_iterator allows us to do the same thing without allocating the extra vector: what we do is simply:

```
// we have sequence1 and sequence2 and assume equal size:
double result = average(
    make_coupling_iterator(sequence1.begin(),
                           sequence2.begin(),
                           std::multiplies<double()),
    make_coupling_iterator(sequence1.end(),
                           sequence2.end(),
                           std::multiplies<double()));
```

The call to make_coupling_iterator creates an iterator which is really a reference to the two iterators and the operation we passed. Dereferencing such iterator returns the result of applying such operation to the values pointed to by the two contained iterators. Advancing the coupling iterator advances the two underlying ones. You can see how iterating on such iterator is quite an alliteration but generates the products one by one so that they can be processed by average(), but does not need allocating memory for storing the results. The product sequence is generated on the fly.

The other iterators share the same principle but have different functionalities:

- combining_iterator is the same of coupling_iterator, but works on N sequences while the latter works on 2;
- filtering_iterator generates the elements of a given sequence which satisfy a given predicate, i.e., it takes a sequence [x_0,x_1,...] and a predicate p and generates the sequence of those x_i for which p(x_i) returns true;

- processing_iterator takes a sequence [x_0,x_1,...] and a function f and generates the sequence [f(x_0),f(x_1),...];
- stepping_iterator takes a sequence [x_0,x_1,...] and a step m and generates the sequence [x_0,x_m,x_2m,...]

Chapter 3

Examples

More examples of using the QuantLib library can be found in chapter 13 of the reference manual. Should your viewer allow it, they can also be reached via the hyperlinks in the following list.

3.1 QuantLib Examples

Here is a list of all examples:

- DiscreteHedging.cpp
- EuropeanOption.cpp
- history_iterators.cpp
- swapvaluation.cpp

Part II

Reference Manual

Chapter 4

QuantLib Module Index

4.1 QuantLib Modules

Here is a list of all modules:

Chapter 5

QuantLib Namespace Index

5.1 QuantLib Namespace List

Here is a list of all documented namespaces with brief descriptions:

Chapter 6

QuantLib Hierarchical Index

6.1 QuantLib Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 7

QuantLib Compound Index

7.1 QuantLib Compound List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 8

QuantLib File Index

8.1 QuantLib File List

Here is a list of all documented files with brief descriptions:

8.2 QuantLib Related Pages

Here is a list of all related documentation pages:

Chapter 9

QuantLib Module Documentation

9.1 Deprecated classes

The use of classes and functions in the above list is deprecated. They will be removed in future releases.

9.2 Global QuantLib macros

Modules

- Math functions
- Numeric limits
- Time functions
- Character functions
- Input/output functions
- Min and max functions
- Template capabilities
- Iterator support

Defines

- #define QL_HEX_VERSION 0x000300b1

  version hexadecimal number.

- #define QL_VERSION "0.3.0b1-20020322"

  version string.

- #define QL_TRACE_LEVEL 0

  global trace level (may be superseded locally by a greater value).

- #define QL_DUMMY_RETURN(x)

  Is a dummy return statement required?

9.2.1 Detailed Description

Global definitions and quite a few macros which help porting the code to different compilers

9.2.2 Define Documentation

9.2.2.1 #define QL_DUMMY_RETURN(x)

Some compilers will issue a warning if it is missing even though it could never be reached during execution, e.g., after a block like

```
if (condition)
    return validResult;
else
    throw HideousError();
```

On the other hand, other compilers will issue a warning if it is present because it cannot be reached. For the code to be portable this macro should be used after the block.

9.3 Math functions

Defines

- #define QL_SQRT std::sqrt
  square root.
- #define QL_FABS std::fabs
  absolute value.
- #define QL_EXP std::exp
  exponential.
- #define QL_LOG std::log
  logarithm.
- #define QL_SIN std::sin
  sine.
- #define QL_COS std::cos
  cosine.
- #define QL_POW std::pow
  power.
- #define QL_MODF std::modf
  floating-point module.

9.3.1 Detailed Description

Some compilers still define math functions them in the global namespace. For the code to be portable these macros should be used instead of the actual functions.

9.4 Numeric limits

Defines

- #define QL_MIN_INT ((std::numeric_limits<int>::min)())
- #define QL_MAX_INT ((std::numeric_limits<int>::max)())
- #define QL_MIN_DOUBLE -((std::numeric_limits<double>::max)())
- #define QL_MAX_DOUBLE ((std::numeric_limits<double>::max)())
- #define QL_EPSILON ((std::numeric_limits<double>::epsilon)())
- #define **QL_MIN_POSITIVE_DOUBLE** ((std::numeric_limits<double>::min)())

9.4.1 Detailed Description

Some compilers do not give an implementation of <limits> yet. For the code to be portable these macros should be used instead of the corresponding method of std::numeric_limits or the corresponding macro defined in <limits.h>.

9.4.2 Define Documentation

9.4.2.1 #define QL_MIN_INT ((std::numeric_limits<int>::min)())

Defines the value of the maximum representable negative integer value

9.4.2.2 #define QL_MAX_INT ((std::numeric_limits<int>::max)())

Defines the value of the maximum representable integer value

9.4.2.3 #define QL_MIN_DOUBLE -((std::numeric_limits<double>::max)())

Defines the value of the maximum representable negative double value

9.4.2.4 #define QL_MAX_DOUBLE ((std::numeric_limits<double>::max)())

Defines the value of the maximum representable double value

9.4.2.5 #define QL_EPSILON ((std::numeric_limits<double>::epsilon)())

Defines the machine precision for operations over doubles

9.5 Time functions

Defines

- #define QL_CLOCK std::clock

  clock value.

- #define QL_TIME std::time

  time value.

9.5.1 Detailed Description

Some compilers still define time functions in the global namespace. For the code to be portable these macros should be used instead of the actual functions.

9.6 Character functions

Defines

- #define QL_STRLEN std::strlen

  string length.

- #define QL_TOUPPER std::toupper

  convert to uppercase.

- #define QL_TOLOWER std::tolower

  convert to lowercase.

9.6.1 Detailed Description

Some compilers still define character functions in the global namespace. For the code to be portable these macros should be used instead of the actual functions.

9.7 Input/output functions

Defines

- #define QL_SPRINTF std::sprintf

  print to string.

9.7.1 Detailed Description

Some compilers still define i/o functions in the global namespace. For the code to be portable these macros should be used instead of the actual functions.

9.8 Min and max functions

Defines

- #define QL_MIN std::min

  minimum between two elements.

- #define QL_MAX std::max

  maximum between two elements.

9.8.1 Detailed Description

Some compilers still do not define std::min and std::max. Moreover, Visual C++ defines them but for unfathomable reasons garble their names. For the code to be portable these macros should be used instead of the actual functions.

9.9 Template capabilities

Defines

- #define QL_DECLARE_TEMPLATE_SPECIALIZATIONS

  Blame Microsoft for this one...

- #define QL_ALLOW_TEMPLATE_METHOD_CALLS 1

  Blame Microsoft for this one...

- #define QL_EXPRESSION_TEMPLATES_WORK 1
- #define QL_TEMPLATE_METAPROGRAMMING_WORKS 1

9.9.1 Detailed Description

Some compilers still do not fully implement the template syntax. These macros can be used to select between alternate implementations of blocks of code, namely, one that takes advantage of template programming techniques and a less efficient one which is compatible with all compilers.

9.9.2 Define Documentation

9.9.2.1 #define QL_DECLARE_TEMPLATE_SPECIALIZATIONS

They decided that a declaration and a definition of a specialized template function amount to a redefinition and should issue a linker error. For the code to be portable, template specializations should be declared (as opposed to defined) only if this macro is defined.

9.9.2.2 #define QL_ALLOW_TEMPLATE_METHOD_CALLS 1

Their compiler cannot cope with method calls such as

```
Handle<Type1> h1(whatever);
h2 = h1.downcast<Type2>();
```

For compatibility, a workaround should be implemented (which of course will be less solid or more comples - as I said, blame Microsoft...)

9.9.2.3 #define QL_EXPRESSION_TEMPLATES_WORK 1

Expression templates techniques (see T. L. Veldhuizen, *Expression templates*, C++ Report, 7(5):26-31, June 1995, available at http://extreme.indiana.edu/~tveldhui/papers) are sometimes too advanced for the template implementation of current compilers.

9.9.2.4 #define QL_TEMPLATE_METAPROGRAMMING_WORKS 1

Template metaprogramming techniques (see T. L. Veldhuizen, *Using C++ Template Metaprograms*, C++ Report, Vol 7 No. 4, May 1995, available at http://extreme.indiana.edu/~tveldhui/papers) are sometimes too advanced for the template implementation of current compilers.

9.10 Iterator support

Defines

- #define QL_ITERATOR std::iterator
- #define QL_ITERATOR_TRAITS std::iterator_traits
- #define QL_SPECIALIZE_ITERATOR_TRAITS(T)
- #define QL_REVERSE_ITERATOR(iterator, type) std::reverse_iterator< iterator >

  Blame Microsoft for this one...

- #define **QL_FULL_ITERATOR_SUPPORT**

9.10.1 Detailed Description

Some compilers still define the iterator struct outside the std namespace, only partially implement it, or do not implement it at all. For the code to be portable these macros should be used instead of the actual functions.

9.10.2 Define Documentation

9.10.2.1 #define QL_ITERATOR std::iterator

Custom iterators should be derived from this struct for the code to be portable.

9.10.2.2 #define QL_ITERATOR_TRAITS std::iterator_traits

For the code to be portable this macro should be used instead of the actual struct.

9.10.2.3 #define QL_SPECIALIZE_ITERATOR_TRAITS(T)

When using the QuantLib implementation of iterator_traits, this macro might be needed to specialize QL_ITERATOR_TRAITS for a pointer to a user-defined type.

9.10.2.4 #define QL_REVERSE_ITERATOR(iterator, type) std::reverse_iterator< iterator >

They decided that `std::reverse_iterator<iterator>` needed an extra template argument. For the code to be portable this macro should be used instead of the actual class.

Chapter 10

QuantLib Namespace Documentation

10.1 QuantLib Namespace Reference

a.k.a. the QuantLib Foundation.

Compounds

- class QuantLib::Arguments
  base class for generic argument groups.
- class QuantLib::Results
  base class for generic result groups.
- class QuantLib::Array
  1-D array used in linear algebra.
- class QuantLib::Calendar
  calendar class.
- class QuantLib::Calendar::CalendarImpl
  abstract base class for calendar implementations.
- class QuantLib::Calendar::WesternCalendarImpl
- class QuantLib::CapFlatVolatilityStructure
  Cap/floor flat volatility structure.
- class QuantLib::CapletForwardVolatilityStructure
  Caplet/floorlet forward volatility structure.
- class QuantLib::CashFlow
  Base class for cash flows.
- class QuantLib::IntegerFormatter
  Formats integers for output.

- class QuantLib::DoubleFormatter
  Formats doubles for output.
- class QuantLib::EuroFormatter
  Formats amounts in Euro for output.
- class QuantLib::RateFormatter
  Formats rates for output.
- class QuantLib::DateFormatter
  Formats dates for output.
- class QuantLib::CurrencyFormatter
  Formats currencies for output.
- class QuantLib::StringFormatter
  Formats strings as lower- or uppercase.
- class QuantLib::Period
  Time period described by a number of a given time unit.
- class QuantLib::Date
  Concrete date class.
- class QuantLib::DayCounter
  day counter class.
- class QuantLib::DayCounter::DayCounterImpl
  abstract base class for day counter implementations.
- class QuantLib::DiffusionProcess
  Diffusion process class.
- class QuantLib::BlackScholesProcess
  Black-Scholes diffusion process class.
- class QuantLib::OrnsteinUhlenbeckProcess
  Ornstein-Uhlenbeck process class.
- class QuantLib::Error
  Base error class.
- class QuantLib::AssertionFailedError
  Specialized error.
- class QuantLib::PreconditionNotSatisfiedError
  Specialized error.
- class QuantLib::PostconditionNotSatisfiedError
  Specialized error.

- class QuantLib::IndexError
  Specialized error.
- class QuantLib::IllegalArgumentError
  Specialized error.
- class QuantLib::IllegalResultError
  Specialized error.
- class QuantLib::OutOfMemoryError
  Specialized error.
- class QuantLib::Exercise
  Exercise class (American, Bermudan or European).
- class QuantLib::Grid
  spatial grid class.
- class QuantLib::TimeGrid
  time grid class.
- class QuantLib::Handle
  Reference-counted pointer.
- class QuantLib::History
  Container for historical data.
- class QuantLib::History::Entry
  single datum in history.
- class QuantLib::History::const_iterator
  random access iterator on history entries.
- class QuantLib::Index
  purely virtual base class for indexes.
- class QuantLib::Instrument
  Abstract instrument class.
- class QuantLib::MarketElement
  purely virtual base class for market observables.
- class QuantLib::SimpleMarketElement
  market element returning a stored value.
- class QuantLib::DerivedMarketElement
  market element whose value depends on another market element.
- class QuantLib::CompositeMarketElement

market element whose value depends on two other market element.

- class QuantLib::Null

  template class providing a null value for a given type.

- class QuantLib::Option

  base option class.

- class QuantLib::OptionValue

  option pricing results.

- class QuantLib::OptionGreeks

  option pricing results.

- class QuantLib::OptionPricingEngine

  base class for option pricing engines.

- class QuantLib::Link

  Relinkable access to a Handle.

- class QuantLib::RelinkableHandle

  Globally accessible relinkable pointer.

- class QuantLib::RiskStatistics

  Risk analysis tool.

- class QuantLib::Scheduler

  Date scheduler.

- class QuantLib::ObjectiveFunction

  Objective function for 1-D solvers.

- class QuantLib::Solver1D

  Abstract base class for 1-D solvers.

- class QuantLib::SwaptionVolatilityStructure

  Swaption volatility structure.

- class QuantLib::TermStructure

  Term structure.

- class QuantLib::ZeroYieldStructure

  Zero yield term structure.

- class QuantLib::DiscountStructure

  Discount factor term structure.

- class QuantLib::ForwardRateStructure

  Forward rate term structure.

- class QuantLib::ImpliedTermStructure

  Implied term structure at a given date in the future.

- class QuantLib::ZeroSpreadedTermStructure

  Term structure with an added spread on the zero yield rate.

- class QuantLib::ForwardSpreadedTermStructure

  Term structure with an added spread on the instantaneous forward rate.

Typedefs

- typedef int Day

  Day number.

- typedef int Year

  Year number.

- typedef int Integer

  integer number.

- typedef double Real

  real number.

- typedef QL_SIZE_T Size

  size of a container.

- typedef double Time

  continuous quantity with 1-year units.

- typedef double DiscountFactor

  used to describe discount factors between dates.

- typedef double Rate

  used to describe interest rates.

- typedef double Spread

  used to describe spreads on interest rates.

Enumerations

- enum RollingConvention { Preceding, ModifiedPreceding, Following, ModifiedFollowing }

  Rolling conventions.

- enum Currency { AUD, BGL, CAD, CHF, CYP, CZK, DEM, DKK, EEK, EUR, GBP, GRD, HKD, HUF, ISK, ITL, JPY, KRW, LTL, LVL, MTL, NOK, NZD, PLZ, ROL, SEK, SGD, SIT, SKK, TRL, USD, ZAR }

  Known currencies.

- enum Weekday { **Sunday** = 1, **Monday** = 2, **Tuesday** = 3, **Wednesday** = 4, **Thursday** = 5, **Friday** = 6, **Saturday** = 7 }
- enum Month { **January** = 1, **February** = 2, **March** = 3, **April** = 4, **May** = 5, **June** = 6, **July** = 7, **August** = 8, **September** = 9, **October** = 10, **November** = 11, **December** = 12 }

  Month names.

- enum TimeUnit { **Days** = 0, **Weeks** = 1, **Months** = 2, **Years** = 3 }

  Units used to describe time periods.

Functions

- double **DotProduct** (const Array &v1, const Array &v2)
- Array **operator+** (const Array &v)
- Array **operator-** (const Array &v)
- Array **operator+** (const Array &v1, const Array &v2)
- Array **operator+** (const Array &v1, double a)
- Array **operator+** (double a, const Array &v2)
- Array **operator-** (const Array &v1, const Array &v2)
- Array **operator-** (const Array &v1, double a)
- Array **operator-** (double a, const Array &v2)
- Array **operator** * (const Array &v1, const Array &v2)
- Array **operator** * (const Array &v1, double a)
- Array **operator** * (double a, const Array &v2)
- Array **operator/** (const Array &v1, const Array &v2)
- Array **operator/** (const Array &v1, double a)
- Array **operator/** (double a, const Array &v2)
- Array **Abs** (const Array &v)
- Array **Sqrt** (const Array &v)
- Array **Log** (const Array &v)
- Array **Exp** (const Array &v)
- std::ostream & **operator**<< (std::ostream &stream, const Array &array)
- bool **operator==** (const Calendar &h1, const Calendar &h2)
- bool **operator!=** (const Calendar &h1, const Calendar &h2)
- std::ostream & **operator**<< (std::ostream &stream, const Date &date)
- int **operator-** (const Date &d1, const Date &d2)
- bool **operator==** (const Date &d1, const Date &d2)
- bool **operator!=** (const Date &d1, const Date &d2)
- bool **operator**< (const Date &d1, const Date &d2)
- bool **operator**<= (const Date &d1, const Date &d2)
- bool **operator**> (const Date &d1, const Date &d2)
- bool **operator**>= (const Date &d1, const Date &d2)
- bool **operator==** (const DayCounter &h1, const DayCounter &h2)
- bool **operator!=** (const DayCounter &h1, const DayCounter &h2)

Variables

- const double **growthFactor** = 1.6

10.1.1 Detailed Description

Armijo linesearch.

Let alpha and beta be 2 scalars in [0,1]. Let x be the current value of the unknow, d the search direction and t the step. Let f be the function to minimize. The line search stop when t verifies f(x+t∗d) - f(x) <= -alpha∗t∗f'(x+t∗d) and f(x+t/beta∗d) - f(x) > -alpha∗t∗f'(x+t∗d)/beta

(see Polak. Algorithms and consitent approximations, Optimization, volume 124 of Applied Mathematical Sciences. Springer-Arrayerlag, N-Y, 1997)

10.1.2 Enumeration Type Documentation

10.1.2.1 enum RollingConvention

These conventions specify the algorithm used to find the business day which is "closest" to a given holiday.

Enumeration values:

Preceding Choose the first business day before the given holiday.

ModifiedPreceding Choose the first business day before the given holiday unless it belongs to a different month, in which case choose the first business day after the holiday.

Following Choose the first business day after the given holiday.

ModifiedFollowing Choose the first business day after the given holiday unless it belongs to a different month, in which case choose the first business day before the holiday.

10.1.2.2 enum Currency

Enumeration values:

AUD Australian Dollar.

BGL Bulgarian Lev.

CAD Canadian Dollar.

CHF Swiss Franc.

CYP Cyprus Pound.

CZK Czech Koruna.

DEM German Mark.

DKK Danish Krone.

EEK Estonian Kroon.

EUR Euro.

GBP British Pound.

GRD Greek Drachma.

HKD Hong Kong Dollar.

HUF Hungarian Forint.

ISK Iceland Krona.

ITL Italian Lira.

JPY Japanese Yen.

KRW South-Korean Won.

LTL Lithuanian Litas.

LVL Latvian Lats.

MTL Maltese Lira.

NOK Norwegian Kroner.

NZD New Zealand Dollar.

PLZ Polish Zloty.

ROL Romanian Leu.

SEK Swedish Krona.

SGD Singapore Dollar.

SIT Slovenian Tolar.

SKK Slovak Koruna.

TRL Turkish Lira.

USD US Dollar.

ZAR South African Rand.

10.1.2.3 enum Weekday

Day's serial number MOD 7; WEEKDAY Excel function is the same except for Sunday = 7

10.2 QuantLib::Calendars Namespace Reference

Specialized Calendar classes.

Compounds

- class QuantLib::Calendars::Frankfurt
  Frankfurt calendar.
- class QuantLib::Calendars::Helsinki
  Helsinki calendar.
- class QuantLib::Calendars::Johannesburg
  Johannesburg calendar.
- class QuantLib::Calendars::London
  London calendar.
- class QuantLib::Calendars::Milan
  Milan calendar.
- class QuantLib::Calendars::NewYork
  New York calendar.
- class QuantLib::Calendars::Sydney
  Sydney, calendar (New South Wales, Australia).
- class QuantLib::Calendars::TARGET
  TARGET calendar.
- class QuantLib::Calendars::Tokyo
  Tokyo calendar.
- class QuantLib::Calendars::Toronto
  Toronto calendar.
- class QuantLib::Calendars::Wellington
  Wellington calendar.
- class QuantLib::Calendars::Zurich
  Zurich calendar.

10.2.1 Detailed Description

See sect. Calendars

10.3 QuantLib::CashFlows Namespace Reference

Concrete implementations of the CashFlow interface.

Compounds

- class QuantLib::CashFlows::FixedRateCouponVector
  helper class building a sequence of fixed rate coupons.
- class QuantLib::CashFlows::FloatingRateCouponVector
  helper class building a sequence of floating rate coupons.
- class QuantLib::CashFlows::Coupon
  coupon accruing over a fixed period.
- class QuantLib::CashFlows::FixedRateCoupon
  coupon paying a fixed interest rate.
- class QuantLib::CashFlows::FloatingRateCoupon
  coupon at par on a term structure.
- class QuantLib::CashFlows::ShortFloatingRateCoupon
  short coupon at par on a term structure.
- class QuantLib::CashFlows::SimpleCashFlow
  Predetermined cash flow.

10.3.1 Detailed Description

See sect. cashflows

10.4 QuantLib::DayCounters Namespace Reference

Specialized DayCounter classes.

Compounds

- class QuantLib::DayCounters::Actual360
  Actual/360 day count convention.
- class QuantLib::DayCounters::Actual365
  Actual/365 day count convention.
- class QuantLib::DayCounters::ActualActual
  Actual/Actual day count.
- class QuantLib::DayCounters::Thirty360
  30/360 day count convention.

10.4.1 Detailed Description

See sect. dayconters

10.5 QuantLib::FiniteDifferences Namespace Reference

Finite difference framework.

Compounds

- class QuantLib::FiniteDifferences::BoundaryCondition
  Boundary condition for finite difference problems.
- class QuantLib::FiniteDifferences::BSMOperator
  Black-Scholes-Merton differential operator.
- class QuantLib::FiniteDifferences::CrankNicolson
  Crank-Nicolson scheme for finite difference methods.
- class QuantLib::FiniteDifferences::DMinus
  D_- *matricial representation.*
- class QuantLib::FiniteDifferences::DPlus
  D_+ *matricial representation.*
- class QuantLib::FiniteDifferences::DPlusDMinus
  D_+D_- *matricial representation.*
- class QuantLib::FiniteDifferences::DZero
  D_0 *matricial representation.*
- class QuantLib::FiniteDifferences::ExplicitEuler
  Forward Euler scheme for finite difference methods.
- class QuantLib::FiniteDifferences::FiniteDifferenceModel
  Generic finite difference model.
- class QuantLib::FiniteDifferences::ImplicitEuler
  Backward Euler scheme for finite difference methods.
- class QuantLib::FiniteDifferences::MixedScheme
  Mixed (explicit/implicit) scheme for finite difference methods.
- class QuantLib::FiniteDifferences::OneFactorOperator
  Interest-rate single factor model differential operator.
- class QuantLib::FiniteDifferences::StepCondition
  condition to be applied at every time step.
- class QuantLib::FiniteDifferences::TridiagonalOperator
  Base implementation for tridiagonal operator.
- class QuantLib::FiniteDifferences::TridiagonalOperator::TimeSetter
  encapsulation of time-setting logic.

Typedefs

- typedef FiniteDifferenceModel< CrankNicolson< TridiagonalOperator > > StandardFiniteDifferenceModel

  default choice for finite-difference model.

- typedef StepCondition< Array > StandardStepCondition

  default choice for step condition.

Functions

- TridiagonalOperator **operator+** (const TridiagonalOperator &D)
- TridiagonalOperator **operator-** (const TridiagonalOperator &D)
- TridiagonalOperator **operator+** (const TridiagonalOperator &D1, const TridiagonalOperator &D2)
- TridiagonalOperator **operator-** (const TridiagonalOperator &D1, const TridiagonalOperator &D2)
- TridiagonalOperator **operator** * (double a, const TridiagonalOperator &D)
- TridiagonalOperator **operator** * (const TridiagonalOperator &D, double a)
- TridiagonalOperator **operator/** (const TridiagonalOperator &D, double a)
- double valueAtCenter (const Array &a)

  mid-point value.

- double firstDerivativeAtCenter (const Array &a, const Array &g)

  mid-point first derivative.

- double secondDerivativeAtCenter (const Array &a, const Array &g)

  mid-point second derivative.

10.5.1 Detailed Description

See sect. The finite differences framework

10.6 QuantLib::Indexes Namespace Reference

Concrete implementations of the Index interface.

Compounds

- class QuantLib::Indexes::AUDLibor
  AUD Libor index (Also known as TIBOR, check settlement days).
- class QuantLib::Indexes::CADLibor
  CAD Libor index (Also known as CDOR, check settlement days).
- class QuantLib::Indexes::CHFLibor
  CHF Libor index (Also known as ZIBOR, check settlement days and day-count).
- class QuantLib::Indexes::Euribor
  Euribor index.
- class QuantLib::Indexes::GBPLibor
  GBP Libor index.
- class QuantLib::Indexes::JPYLibor
  JPY Libor index (Also known as TIBOR, check settlement days).
- class QuantLib::Indexes::USDLibor
  USD Libor index.
- class QuantLib::Indexes::Xibor
  base class for libor indexes.
- class QuantLib::Indexes::XiborManager
  global repository for libor histories.
- class QuantLib::Indexes::ZARLibor
  ZAR Libor index (also known as JIBAR, check settlement days).

10.6.1 Detailed Description

See sect. indexes

10.7 QuantLib::Instruments Namespace Reference

Concrete implementations of the Instrument interface.

Compounds

- class QuantLib::Instruments::CapFloorParameters
  parameters for cap/floor calculation.
- class QuantLib::Instruments::CapFloorResults
  results from cap/floor calculation.
- class QuantLib::Instruments::PlainOption
  Plain (no dividends, no barriers) option on a single asset.
- class QuantLib::Instruments::PlainOptionParameters
  parameters for plain option calculation.
- class QuantLib::Instruments::PlainOptionResults
  results from plain option calculation.
- class QuantLib::Instruments::SimpleSwap
  Simple fixed-rate vs Libor swap.
- class QuantLib::Instruments::Stock
  Simple stock class.
- class QuantLib::Instruments::Swap
  Interest rate swap.
- class QuantLib::Instruments::Swaption
  Swaption class.
- class QuantLib::Instruments::SwaptionParameters
  parameters for swaption calculation.
- class QuantLib::Instruments::SwaptionResults
  results from swaption calculation.

10.7.1 Detailed Description

See sect. Instruments and pricers

10.8 QuantLib::Math Namespace Reference

Mathematical functions and classes.

Compounds

- class QuantLib::Math::BilinearInterpolation

  bilinear interpolation between discrete points.

- class QuantLib::Math::CubicSpline

  cubic spline interpolation between discrete points.

- class QuantLib::Math::Interpolation

  abstract base class for 1-D interpolations.

- class QuantLib::Math::Interpolation2D

  abstract base class for 2-D interpolations.

- class QuantLib::Math::LexicographicalView

  Lexicographical 2-D view of a contiguous set of data.

- class QuantLib::Math::LinearInterpolation

  linear interpolation between discrete points.

- class QuantLib::Math::Matrix

  matrix used in linear algebra.

- class QuantLib::Math::MultivariateAccumulator

  A sample accumulator for multivariate analysis.

- class QuantLib::Math::RiskMeasures

  Interface for risk functions.

- class QuantLib::Math::SegmentIntegral

  Integral of a one-dimensional function.

- class QuantLib::Math::Statistics

  Statistic tool.

- class QuantLib::Math::SymmetricSchurDecomposition

  symmetric threshold Jacobi algorithm.

Typedefs

- typedef NormalDistribution **GaussianDistribution**

Functions

- Matrix **matrixSqrt** (const Matrix &realSymmMatrix)
- Matrix **operator+** (const Matrix &m1, const Matrix &m2)
- Matrix **operator-** (const Matrix &m1, const Matrix &m2)
- Matrix **operator** ∗ (const Matrix &m, double x)
- Matrix **operator** ∗ (double x, const Matrix &m)
- Matrix **operator/** (const Matrix &m, double x)
- Array **operator** ∗ (const Array &v, const Matrix &m)
- Array **operator** ∗ (const Matrix &m, const Array &v)
- Matrix **operator** ∗ (const Matrix &m1, const Matrix &m2)
- Matrix **transpose** (const Matrix &m)
- Matrix **outerProduct** (const Array &v1, const Array &v2)
- Array **SymmetricEigenvalues** (Matrix &s)
- Matrix **SymmetricEigenvectors** (Matrix &s)

10.8.1 Detailed Description

See sect. Math tools

10.9 QuantLib::MonteCarlo Namespace Reference

Monte Carlo framework.

Compounds

- class QuantLib::MonteCarlo::ArithmeticAPOPathPricer
  path pricer for arithmetic average price option.
- class QuantLib::MonteCarlo::ArithmeticASOPathPricer
  path pricer for average strike Asian options.
- class QuantLib::MonteCarlo::BasketPathPricer
  multipath pricer for European-type basket option.
- class QuantLib::MonteCarlo::EuropeanPathPricer
  path pricer for European options.
- class QuantLib::MonteCarlo::EverestPathPricer
  path pricer for European-type Everest option.
- class QuantLib::MonteCarlo::GeometricAPOPathPricer
  path pricer for geometric average price option.
- class QuantLib::MonteCarlo::GeometricASOPathPricer
  path pricer for geometric average price option.
- class QuantLib::MonteCarlo::HimalayaPathPricer
  multipath pricer for European-type Himalaya option.
- class QuantLib::MonteCarlo::MaxBasketPathPricer
  multipath pricer for European-type basket option.
- class QuantLib::MonteCarlo::MonteCarloModel
  General purpose Monte Carlo model for path samples.
- class QuantLib::MonteCarlo::MultiPath
  single random walk.
- class QuantLib::MonteCarlo::MultiPathGenerator
  Generates a multipath from a random number generator.
- class QuantLib::MonteCarlo::PagodaPathPricer
  multipath pricer for pagoda options.
- class QuantLib::MonteCarlo::Path
  single factor random walk.
- class QuantLib::MonteCarlo::PathGenerator

Generates random paths from a random number generator.

- class QuantLib::MonteCarlo::PathPricer

  base class for path pricers.

- struct QuantLib::MonteCarlo::Sample

  weighted sample.

Typedefs

- typedef PathGenerator< RandomNumbers::GaussianRandomGenerator > GaussianPathGenerator

  default choice for Gaussian path generator.

- typedef MultiPathGenerator< RandomNumbers::RandomArrayGenerator< RandomNumbers::GaussianRandomGenerator > > GaussianMultiPathGenerator

  default choice for Gaussian multi-path generator.

- typedef MonteCarloModel< Math::Statistics, GaussianPathGenerator, PathPricer< Path > > OneFactorMonteCarloOption

  default choice for one-factor Monte Carlo model.

- typedef MonteCarloModel< Math::Statistics, GaussianMultiPathGenerator, PathPricer< MultiPath > > MultiFactorMonteCarloOption

  default choice for multi-factor Monte Carlo model.

Functions

- Matrix **getCovariance** (const Array &volatilities, const Matrix &correlations)
- Math::Matrix getCovariance (const Array &volatilities, const Math::Matrix &correlations)

10.9.1 Detailed Description

See sect. The Monte Carlo framework

10.9.2 Function Documentation

10.9.2.1 Math::Matrix getCovariance (const Array & *volatilities*, const Math::Matrix & *correlations*)

Combines the correlation matrix and the vector of volatilities to return the covariance matrix. Note that only the symmetric part of the correlation matrix is used. Also it is assumed that the diagonal member of the correlation matrix equals one.

10.10 QuantLib::Patterns Namespace Reference

Implementations of design patterns.

Compounds

- class QuantLib::Patterns::Observable

  Object that notifies its changes to a set of observables.

- class QuantLib::Patterns::Observer

  Object that gets notified when a given observable changes.

10.10.1 Detailed Description

See sect. Design patterns

10.11 QuantLib::Pricers Namespace Reference

Pricing models for options.

Compounds

- class QuantLib::Pricers::CapFloorPricingEngine
  base class for cap/floor pricing engines.
- class QuantLib::Pricers::PlainOptionEngine
  base class for plain option pricing engines.
- class QuantLib::Pricers::SwaptionPricingEngine
  base class for swaption pricing engines.
- class QuantLib::Pricers::AnalyticalCapFloor
  Analytical pricer for cap/floor.
- class QuantLib::Pricers::BarrierOption
  Barrier option.
- class QuantLib::Pricers::BinaryOption
  Binary (digital) option.
- class QuantLib::Pricers::BlackCapFloor
  CapFloor priced by the Black formula.
- class QuantLib::Pricers::BlackSwaption
  Swaption priced by the Black formula.
- class QuantLib::Pricers::CliquetOption
  cliquet (Ratchet) option.
- class QuantLib::Pricers::ContinuousGeometricAPO
  Continuous Geometric Average Price Option (European exercise).
- class QuantLib::Pricers::DiscreteGeometricAPO
  Discrete Geometric Average Price Asian Option (European style).
- class QuantLib::Pricers::DiscreteGeometricASO
  Discrete Geometric Average Strike Asian Option (European style).
- class QuantLib::Pricers::EuropeanEngine
  analytic pricing engine for European options.
- class QuantLib::Pricers::EuropeanOption
  Black-Scholes-Merton European option.
- class QuantLib::Pricers::FdAmericanOption

American option.

- class QuantLib::Pricers::FdBermudanOption
  Bermudan option.
- class QuantLib::Pricers::FdBsmOption
  Black-Scholes-Merton option priced numerically.
- class QuantLib::Pricers::FdDividendEuropeanOption
  European option with dividends.
- class QuantLib::Pricers::FdDividendShoutOption
  Shout option with dividends.
- class QuantLib::Pricers::FdEuropean
  Example of European option calculated using finite differences.
- class QuantLib::Pricers::FdStepConditionOption
  option executing additional code at each time step.
- class QuantLib::Pricers::JamshidianSwaption
  Jamshidian swaption pricer.
- class QuantLib::Pricers::McBasket
  simple example of multi-factor Monte Carlo pricer.
- class QuantLib::Pricers::McDiscreteArithmeticAPO
  example of Monte Carlo pricer using a control variate.
- class QuantLib::Pricers::McDiscreteArithmeticASO
  example of Monte Carlo pricer using a control variate.
- class QuantLib::Pricers::McEuropean
  simple example of Monte Carlo pricer.
- class QuantLib::Pricers::McEverest
  Everest-type option pricer.
- class QuantLib::Pricers::McHimalaya
  Himalayan-type option pricer.
- class QuantLib::Pricers::McMaxBasket
  simple example of multi-factor Monte Carlo pricer.
- class QuantLib::Pricers::McPagoda
  roofed Asian option.
- class QuantLib::Pricers::McPricer
  base class for Monte Carlo pricers.

- class QuantLib::Pricers::SingleAssetOption

  Black-Scholes-Merton option.

- class QuantLib::Pricers::TreeCapFloor

  Cap/Floor priced in a tree.

- class QuantLib::Pricers::TreeSwaption

  Swaption priced in a tree.

Functions

- double **ExercisePayoff** (Option::Type type, double price, double strike)

10.11.1 Detailed Description

See sect. pricers

10.12 QuantLib::RandomNumbers Namespace Reference

Random Number Generators and Low Discrepancy Sequences.

Compounds

- class QuantLib::RandomNumbers::BoxMullerGaussianRng
  Gaussian random number generator.
- class QuantLib::RandomNumbers::CLGaussianRng
  Gaussian random number generator.
- class QuantLib::RandomNumbers::ICGaussianRng
  Inverse cumulative Gaussian random number generator.
- class QuantLib::RandomNumbers::KnuthUniformRng
  Uniform random number generator.
- class QuantLib::RandomNumbers::LecuyerUniformRng
  Uniform random number generator.
- class QuantLib::RandomNumbers::RandomArrayGenerator
  Generates random arrays from a random number generator.

Typedefs

- typedef LecuyerUniformRng UniformRandomGenerator
  default choice for uniform random number generator.
- typedef BoxMullerGaussianRng< UniformRandomGenerator > GaussianRandomGenerator
  default choice for Gaussian random number generator.
- typedef RandomArrayGenerator< GaussianRandomGenerator > GaussianArrayGenerator
  default choice for Gaussian array generator.

10.12.1 Detailed Description

See sect. Random number and low discrepancy sequence generators

10.13 QuantLib::Solvers1D Namespace Reference

Concrete implementations of the Solver1D interface.

Compounds

- class QuantLib::Solvers1D::Bisection
  bisection 1-D solver.
- class QuantLib::Solvers1D::Brent
  Brent 1-D solver.
- class QuantLib::Solvers1D::FalsePosition
  False position 1-D solver.
- class QuantLib::Solvers1D::Newton
  Newton 1-D solver.
- class QuantLib::Solvers1D::NewtonSafe
  safe Newton 1-D solver.
- class QuantLib::Solvers1D::Ridder
  Ridder 1-D solver.
- class QuantLib::Solvers1D::Secant
  secant 1-D solver.

10.13.1 Detailed Description

See sect. One-dimensional solvers

10.14 QuantLib::TermStructures Namespace Reference

Concrete implementations of the TermStructure interface.

Compounds

- class QuantLib::TermStructures::PiecewiseFlatForward
  Piecewise flat forward term structure.
- class QuantLib::TermStructures::RateHelper
  base class for rate helpers.
- class QuantLib::TermStructures::DepositRateHelper
  Deposit rate.
- class QuantLib::TermStructures::FraRateHelper
  Forward rate agreement.
- class QuantLib::TermStructures::FuturesRateHelper
  Interest Rate Futures.
- class QuantLib::TermStructures::SwapRateHelper
  swap rate.

10.14.1 Detailed Description

See sect. Term structures

10.15 QuantLib::Utilities Namespace Reference

Classes and functions of general utility.

Compounds

- class QuantLib::Utilities::combining_iterator
  Iterator mapping a function to a set of underlying sequences.
- class QuantLib::Utilities::coupling_iterator
  Iterator mapping a function to a pair of underlying sequences.
- class QuantLib::Utilities::filtering_iterator
  Iterator filtering undesired data.
- struct QuantLib::Utilities::lowest_category_iterator
  most generic of two given iterator categories.
- class QuantLib::Utilities::processing_iterator
  Iterator mapping a unary function to an underlying sequence.
- class QuantLib::Utilities::stepping_iterator
  Iterator advancing in constant steps.

10.15.1 Detailed Description

See sect. Utilities

Chapter 11

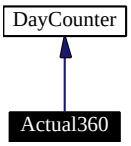
QuantLib Class Documentation

11.1 QuantLib::DayCounters::Actual360 Class Reference

Actual/360 day count convention.

`#include <actual360.hpp>`

Inheritance diagram for QuantLib::DayCounters::Actual360:



Public Methods

- **Actual360** ()

The documentation for this class was generated from the following file:

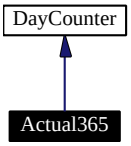
- actual360.hpp

11.2 QuantLib::DayCounters::Actual365 Class Reference

Actual/365 day count convention.

`#include <actual365.hpp>`

Inheritance diagram for QuantLib::DayCounters::Actual365:



Public Methods

- **Actual365** ()

The documentation for this class was generated from the following file:

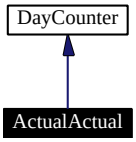
- actual365.hpp

11.3 QuantLib::DayCounters::ActualActual Class Reference

Actual/Actual day count.

`#include <actualactual.hpp>`

Inheritance diagram for QuantLib::DayCounters::ActualActual:



Public Types

- enum **Convention** { **ISMA**, **Bond**, **ISDA**, **Historical**, **AFB**, **Euro** }

Public Methods

- **ActualActual** (Convention c=ActualActual::ISMA)

11.3.1 Detailed Description

The day count can be calculated according to ISMA and US Treasury convention, also known as "Actual/Actual (Bond)"; to ISDA, also known as "Actual/Actual (Historical)"; or to AFB, also known as "Actual/Actual (Euro)".

For more details, refer to `http://www.isda.org/c_and_a/pdf/mktc1198.pdf`

The documentation for this class was generated from the following files:

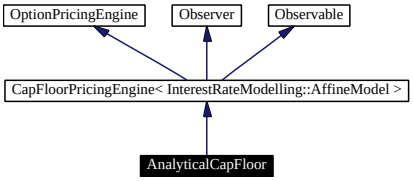
- actualactual.hpp
- actualactual.cpp

11.4 QuantLib::Pricers::AnalyticalCapFloor Class Reference

Analytical pricer for cap/floor.

`#include <analyticalcapfloor.hpp>`

Inheritance diagram for QuantLib::Pricers::AnalyticalCapFloor:



Public Methods

- **AnalyticalCapFloor** (const Handle< InterestRateModelling::AffineModel > &model)
- void **calculate** () const

The documentation for this class was generated from the following files:

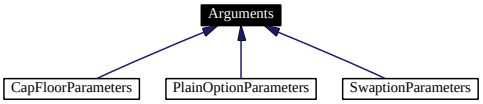
- analyticalcapfloor.hpp
- analyticalcapfloor.cpp

11.5 QuantLib::Arguments Class Reference

base class for generic argument groups.

`#include <argsandresults.hpp>`

Inheritance diagram for QuantLib::Arguments:



Public Methods

- virtual ~**Arguments** ()

The documentation for this class was generated from the following file:

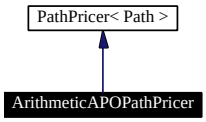
- argsandresults.hpp

11.6 QuantLib::MonteCarlo::ArithmeticAPOPathPricer Class Reference

path pricer for arithmetic average price option.

`#include <arithmeticapopathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::ArithmeticAPOPathPricer:



Public Methods

- **ArithmeticAPOPathPricer** (Option::Type type, double underlying, double strike, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const Path &path) const

The documentation for this class was generated from the following files:

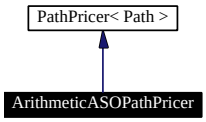
- arithmeticapopathpricer.hpp
- arithmeticapopathpricer.cpp

11.7 QuantLib::MonteCarlo::ArithmeticASOPathPricer Class Reference

path pricer for average strike Asian options.

`#include <arithmeticasopathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::ArithmeticASOPathPricer:



Public Methods

- **ArithmeticASOPathPricer** (Option::Type type, double underlying, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const Path &path) const

The documentation for this class was generated from the following files:

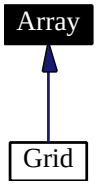
- arithmeticasopathpricer.hpp
- arithmeticasopathpricer.cpp

11.8 QuantLib::Array Class Reference

1-D array used in linear algebra.

`#include <array.hpp>`

Inheritance diagram for QuantLib::Array:



Public Types

- typedef double * **iterator**
- typedef const double * **const_iterator**

Public Methods

- typedef **QL_REVERSE_ITERATOR** (iterator, double) reverse_iterator
- typedef **QL_REVERSE_ITERATOR** (const_iterator, double) const _reverse_iterator

Constructors, destructor, and assignment

- Array (Size size=0)

  creates the array with the given dimension.

- Array (Size size, double value)

  creates the array and fills it with `value`.

- Array (Size size, double value, double increment)

  creates the array and fills it according to $a_0 = value, a_i = a_{i-1} + increment$.

- **Array** (const Array &from)
- ~**Array** ()
- Array & **operator=** (const Array &from)

Vector algebra

`v += x` *and similar operation involving a scalar value are shortcuts for* $\forall i : v_i = v_i + x$

`v *= w` *and similar operation involving two vectors are shortcuts for* $\forall i : v_i = v_i \times w_i$

This implementation was inspired by T. L. Veldhuizen, Expression templates, *C++ Report, 7(5):26-31, June 1995 available at* `http://extreme.indiana.edu/~tveldhui/papers/`

Precondition:

all arrays involved in an algebraic expression must have the same size.

- Array & **operator+=** (const Array &)
- Array & **operator+=** (double)
- Array & **operator-=** (const Array &)

- Array & **operator-=** (double)
- Array & **operator** ∗= (const Array &)
- Array & **operator** ∗= (double)
- Array & **operator/=** (const Array &)
- Array & **operator/=** (double)

Element access

- double operator[ ] (Size) const
  read-only.
- double & operator[ ] (Size)
  read-write.

Inspectors

- Size size () const
  dimension of the array.

Iterator access

- const_iterator **begin** () const
- iterator **begin** ()
- const_iterator **end** () const
- iterator **end** ()
- const_reverse_iterator **rbegin** () const
- reverse_iterator **rbegin** ()
- const_reverse_iterator **rend** () const
- reverse_iterator **rend** ()

Related Functions

(Note that these are not member functions.)

- double **DotProduct** (const Array &, const Array &)
- Array **operator+** (const Array &v)
- Array **operator-** (const Array &v)
- Array **operator+** (const Array &, const Array &)
- Array **operator+** (const Array &, double)
- Array **operator+** (double, const Array &)
- Array **operator-** (const Array &, const Array &)
- Array **operator-** (const Array &, double)
- Array **operator-** (double, const Array &)
- Array **operator** ∗ (const Array &, const Array &)
- Array **operator** ∗ (const Array &, double)
- Array **operator** ∗ (double, const Array &)
- Array **operator/** (const Array &, const Array &)
- Array **operator/** (const Array &, double)
- Array **operator/** (double, const Array &)
- Array **Abs** (const Array &)
- Array **Sqrt** (const Array &)
- Array **Log** (const Array &)
- Array **Exp** (const Array &)

11.8.1 Detailed Description

This class implements the concept of vector as used in linear algebra. As such, it is **not** meant to be used as a container - `std::vector` should be used instead.

The documentation for this class was generated from the following file:

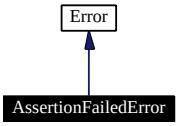
- array.hpp

11.9 QuantLib::AssertionFailedError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::AssertionFailedError:



Public Methods

- **AssertionFailedError** (const std::string &what="")

11.9.1 Detailed Description

Thrown upon a failed assertion.

The documentation for this class was generated from the following file:

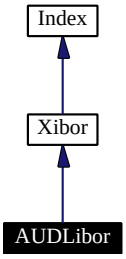
- errors.hpp

11.10 QuantLib::Indexes::AUDLibor Class Reference

AUD Libor index (Also known as TIBOR, check settlement days).

`#include <audlibor.hpp>`

Inheritance diagram for QuantLib::Indexes::AUDLibor:



Public Methods

- **AUDLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

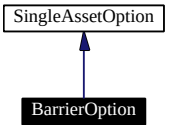
- audlibor.hpp

11.11 QuantLib::Pricers::BarrierOption Class Reference

Barrier option.

`#include <ql/Pricers/barrieroption.hpp>`

Inheritance diagram for QuantLib::Pricers::BarrierOption:



Public Types

- enum **BarrierType** { **DownIn**, **UpIn**, **DownOut**, **UpOut** }

Public Methods

- **BarrierOption** (BarrierType barrType, Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, double barrier, double rebate=0.0)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- Handle< SingleAssetOption > **clone** () const

Protected Methods

- void **calculate_** () const

Protected Attributes

- double **greeksCalculated_**
- double **delta_**
- double **gamma_**
- double **theta_**

11.11.1 Detailed Description

The analytical calculation are taken from "Option pricing formulas", E.G. Haug, McGraw-Hill, p.69 and following.

The documentation for this class was generated from the following files:

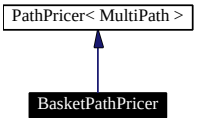
- barrieroption.hpp
- barrieroption.cpp

11.12 QuantLib::MonteCarlo::BasketPathPricer Class Reference

multipath pricer for European-type basket option.

`#include <basketpathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::BasketPathPricer:



Public Methods

- **BasketPathPricer** (Option::Type type, const Array &underlying, double strike, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const MultiPath &multiPath) const

11.12.1 Detailed Description

The value of the option at expiration is given by the value of the underlying which has best performed.

The documentation for this class was generated from the following files:

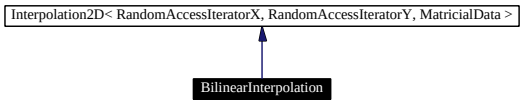
- basketpathpricer.hpp
- basketpathpricer.cpp

11.13 QuantLib::Math::BilinearInterpolation Class Template Reference

bilinear interpolation between discrete points.

`#include <bilinearinterpolation.hpp>`

Inheritance diagram for QuantLib::Math::BilinearInterpolation:



Public Types

- typedef double **result_type**

Public Methods

- **BilinearInterpolation** (const RandomAccessIteratorX &xBegin, const RandomAccessIteratorX &xEnd, const RandomAccessIteratorY &yBegin, const RandomAccessIteratorY &yEnd, const MatricialData &data, bool allowExtrapolation)
- double operator() (const first_argument_type &x, const second_argument_type &y) const

Public Attributes

- typedef< RandomAccessIteratorX >::value_type **first_argument_type**
- typedef< RandomAccessIteratorY >::value_type **second_argument_type**

template<class RandomAccessIteratorX, class RandomAccessIteratorY, class MatricialData> class QuantLib::Math::BilinearInterpolation< RandomAccessIteratorX, RandomAccessIteratorY, MatricialData >

11.13.1 Member Function Documentation

11.13.1.1 double operator() (const first_argument_type & *x*, const second_argument_type & *y*) const [virtual]

This operator must be overridden to provide an implementation of the actual interpolation.

Precondition:
The sequence of values for x must have been sorted for the result to make sense.

Implements QuantLib::Math::Interpolation2D.

The documentation for this class was generated from the following file:

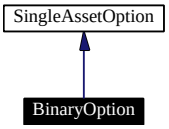
- bilinearinterpolation.hpp

11.14 QuantLib::Pricers::BinaryOption Class Reference

Binary (digital) option.

`#include <binaryoption.hpp>`

Inheritance diagram for QuantLib::Pricers::BinaryOption:



Public Methods

- **BinaryOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, double cashPayoff=1)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- double **vega** () const
- double **rho** () const
- double **dividendRho** () const
- Handle< SingleAssetOption > **clone** () const

The documentation for this class was generated from the following files:

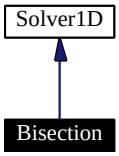
- binaryoption.hpp
- binaryoption.cpp

11.15 QuantLib::Solvers1D::Bisection Class Reference

bisection 1-D solver.

`#include <bisection.hpp>`

Inheritance diagram for QuantLib::Solvers1D::Bisection:



Protected Methods

- double solve_ (const ObjectiveFunction &f, double xAccuracy) const

11.15.1 Member Function Documentation

11.15.1.1 double solve_ (const ObjectiveFunction & *f*, double *xAccuracy*) const [protected, virtual]

This method must be implemented in derived classes and contains the actual code which searches for the zeroes of the ObjectiveFunction. It assumes that:

- **xMin_** and **xMax_** form a valid bracket;
- **fxMin_** and **fxMax_** contain the values of the function in **xMin_** and **xMax_**;
- **root_** was initialized to a valid initial guess.

Implements QuantLib::Solver1D.

The documentation for this class was generated from the following files:

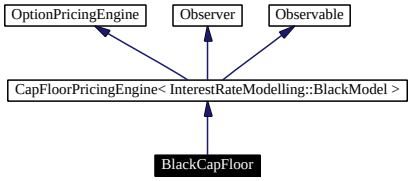
- bisection.hpp
- bisection.cpp

11.16 QuantLib::Pricers::BlackCapFloor Class Reference

CapFloor priced by the Black formula.

`#include <blackcapfloor.hpp>`

Inheritance diagram for QuantLib::Pricers::BlackCapFloor:



Public Methods

- **BlackCapFloor** (const Handle< InterestRateModelling::BlackModel > &mod)
- void **calculate** () const

The documentation for this class was generated from the following files:

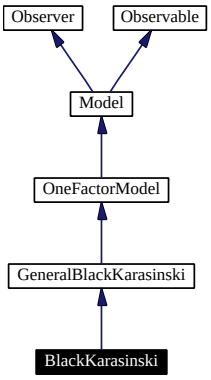
- blackcapfloor.hpp
- blackcapfloor.cpp

11.17 QuantLib::InterestRateModelling::BlackKarasinski Class Reference

Standard Black-Karasinski model class.

`#include <blackkarasinski.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::BlackKarasinski:



Public Methods

- **BlackKarasinski** (const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**BlackKarasinski** ()

11.17.1 Detailed Description

This class implements the standard Black-Karasinski model defined by $d\ln r_t = (\theta(t) - \alpha \ln r_t)dt + \sigma dW_t$. where $alpha$ and $sigma$ are constants.

The documentation for this class was generated from the following file:

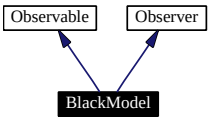
- blackkarasinski.hpp

11.18 QuantLib::InterestRateModelling::BlackModel Class Reference

Abstract short-rate model class.

`#include <blackmodel.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::BlackModel:



Public Methods

- **BlackModel** (const RelinkableHandle< MarketElement > &volatility, const RelinkableHandle< TermStructure > &termStructure)
- double **volatility** () const
- const RelinkableHandle< TermStructure > & **termStructure** () const
- void update ()

Static Public Methods

- double **formula** (double k, double f, double v, double w)

11.18.1 Member Function Documentation

11.18.1.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

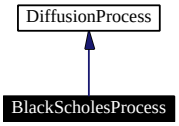
- blackmodel.hpp

11.19 QuantLib::BlackScholesProcess Class Reference

Black-Scholes diffusion process class.

`#include <diffusionprocess.hpp>`

Inheritance diagram for QuantLib::BlackScholesProcess:



Public Methods

- **BlackScholesProcess** (Rate rate, double volatility, double s0=0.0)
- virtual double **drift** (Time t, double x) const
- virtual double **diffusion** (Time t, double x) const
- virtual double expectation (Time t0, double x0, Time dt) const

  Euler approximation of the expectation.

- virtual double variance (Time t0, double x0, Time dt) const

  Euler approximation of the variance.

11.19.1 Detailed Description

This class describes the stochastic process governed by

$$dS = rdt + \sigma dW_t$$

.

The documentation for this class was generated from the following file:

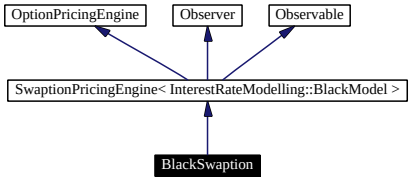
- diffusionprocess.hpp

11.20 QuantLib::Pricers::BlackSwaption Class Reference

Swaption priced by the Black formula.

`#include <blackswaption.hpp>`

Inheritance diagram for QuantLib::Pricers::BlackSwaption:



Public Methods

- **BlackSwaption** (const Handle< InterestRateModelling::BlackModel > &mod)
- void **calculate** () const

The documentation for this class was generated from the following files:

- blackswaption.hpp
- blackswaption.cpp

11.21 QuantLib::FiniteDifferences::BoundaryCondition Class Reference

Boundary condition for finite difference problems.

`#include <boundarycondition.hpp>`

Public Types

- enum **Type** { **None**, **Neumann**, **Dirichlet** }

Public Methods

- **BoundaryCondition** (Type type=None, double value=Null< double >())
- Type **type** () const
- double **value** () const

11.21.1 Detailed Description

Three possibilities are given for setting boundary conditions, namely, no boundary condition, Dirichlet boundary condition (i.e., constant value), and Neumann boundary condition (i.e., constant derivative).

Warning:
For Neumann conditions. the value passed must not be the value of the derivative. Instead, it must be comprehensive of the grid step between the first two points–i.e., it must be the difference between f[0] and f[1].

The documentation for this class was generated from the following file:

- boundarycondition.hpp

11.22 QuantLib::RandomNumbers::BoxMullerGaussianRng Class Template Reference

Gaussian random number generator.

`#include <boxmullergaussianrng.hpp>`

Public Types

- typedef MonteCarlo::Sample< double > **sample_type**

Public Methods

- **BoxMullerGaussianRng** (long seed=0)
- sample_type next () const

  returns next sample from the Gaussian distribution.

11.22.1 Detailed Description

template<class U> class QuantLib::RandomNumbers::BoxMullerGaussianRng< U >

It uses the well-known Box-Muller transformation to return a normal distributed Gaussian deviate with average 0.0 and standard deviation of 1.0, from a uniform deviate in (0,1) supplied by U.

Class U must implement the following interface:

```
U::U(long seed);
U::sample_type U::next() const;
```

The documentation for this class was generated from the following file:

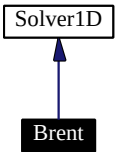
- boxmullergaussianrng.hpp

11.23 QuantLib::Solvers1D::Brent Class Reference

Brent 1-D solver.

`#include <brent.hpp>`

Inheritance diagram for QuantLib::Solvers1D::Brent:



The documentation for this class was generated from the following files:

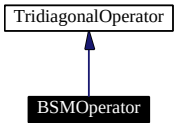
- brent.hpp
- brent.cpp

11.24 QuantLib::FiniteDifferences::BSMOperator Class Reference

Black-Scholes-Merton differential operator.

`#include <bsmoperator.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::BSMOperator:



Public Methods

- **BSMOperator** ()
- **BSMOperator** (Size size, double dx, double r, double q, double sigma)

The documentation for this class was generated from the following files:

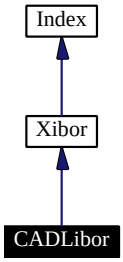
- bsmoperator.hpp
- bsmoperator.cpp

11.25 QuantLib::Indexes::CADLibor Class Reference

CAD Libor index (Also known as CDOR, check settlement days).

`#include <cadlibor.hpp>`

Inheritance diagram for QuantLib::Indexes::CADLibor:



Public Methods

- **CADLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

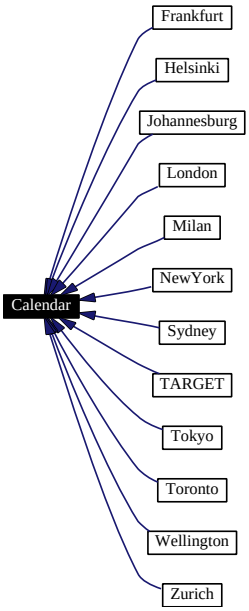
- cadlibor.hpp

11.26 QuantLib::Calendar Class Reference

calendar class.

`#include <calendar.hpp>`

Inheritance diagram for QuantLib::Calendar:



Public Methods

Calendar interface

- std::string name () const
  Returns the name of the calendar.
- bool isBusinessDay (const Date &d) const
- bool isHoliday (const Date &d) const
- Date roll (const Date &, RollingConvention convention=Following) const
- Date advance (const Date &, int n, TimeUnit unit, RollingConvention convention=Following) const

Protected Methods

- Calendar (const Handle< CalendarImpl > &impl)

Related Functions

(Note that these are not member functions.)

- bool operator== (const Calendar &, const Calendar &)
- bool **operator!=** (const Calendar &, const Calendar &)

11.26.1 Detailed Description

This class provides methods for determining whether a date is a business day or a holiday for a given market, and for incrementing/decrementing a date of a given number of business days.

The Strategy pattern is used to provide the base behavior of the calendar, namely, to determine whether a date is a business day.

11.26.2 Constructor & Destructor Documentation

11.26.2.1 Calendar (const Handle< CalendarImpl > & *impl*) [inline, protected]

this protected constructor will only be invoked by derived classes which define a given Calendar implementation

11.26.3 Member Function Documentation

11.26.3.1 std::string name () const [inline]

Warning:

This method is used for output and comparison between calendars. It is **not** meant to be used for writing switch-on-type code.

11.26.3.2 bool isBusinessDay (const Date & *d*) const [inline]

Returns `true` iff the date is a business day for the given market.

11.26.3.3 bool isHoliday (const Date & *d*) const [inline]

Returns `true` iff the date is a holiday for the given market.

11.26.3.4 Date roll (const Date &, RollingConvention *convention* = Following) const

Returns the next business day on the given market with respect to the given date and convention.

11.26.3.5 Date advance (const Date &, int *n*, TimeUnit *unit*, RollingConvention *convention* = Following) const

Advances the given date of the given number of business days and returns the result.

Note:

The input date is not modified.

11.26.4 Friends And Related Function Documentation

11.26.4.1 bool operator== (const Calendar &, const Calendar &) [related]

Returns `true` iff the two calendars belong to the same derived class.

The documentation for this class was generated from the following files:

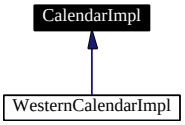
- calendar.hpp
- calendar.cpp

11.27 QuantLib::Calendar::CalendarImpl Class Reference

abstract base class for calendar implementations.

`#include <calendar.hpp>`

Inheritance diagram for QuantLib::Calendar::CalendarImpl:



Public Methods

- virtual std::string **name** () const=0
- virtual bool **isBusinessDay** (const Date &) const=0

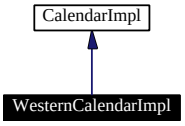
The documentation for this class was generated from the following file:

- calendar.hpp

11.28 QuantLib::Calendar::WesternCalendarImpl Class Reference

`#include <calendar.hpp>`

Inheritance diagram for QuantLib::Calendar::WesternCalendarImpl:



Static Protected Methods

- Day easterMonday (Year y)

  expressed relative to first day of year.

11.28.1 Detailed Description

partial implementation providing the means of determining the Easter Monday for a given year.

The documentation for this class was generated from the following files:

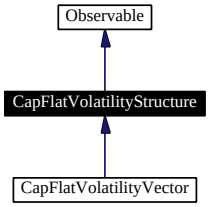
- calendar.hpp
- calendar.cpp

11.29 QuantLib::CapFlatVolatilityStructure Class Reference

Cap/floor flat volatility structure.

`#include <capvolstructures.hpp>`

Inheritance diagram for QuantLib::CapFlatVolatilityStructure:



Public Methods

- virtual ~**CapFlatVolatilityStructure** ()
- virtual Date todaysDate () const=0
  returns today's date.
- virtual Date settlementDate () const=0
  returns the settlement date.
- virtual DayCounter dayCounter () const=0
  returns the day counter used for internal date/time conversions.
- double volatility (const Date &end, Rate strike) const
  returns the volatility for a given end date and strike rate.
- double volatility (const Period &length, Rate strike) const
  returns the volatility for a given cap/floor length and strike rate.
- double volatility (Time t, Rate strike) const
  returns the volatility for a given end time and strike rate.

Protected Methods

- virtual double volatilityImpl (Time length, Rate strike) const=0
  implements the actual volatility calculation in derived classes.

11.29.1 Detailed Description

This class is purely abstract and defines the interface of concrete structures which will be derived from this one.

The documentation for this class was generated from the following file:

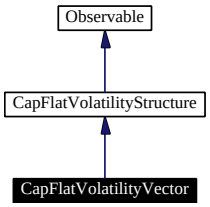
- capvolstructures.hpp

11.30 QuantLib::Volatilities::CapFlatVolatilityVector Class Reference

Cap/floor at-the-money flat volatility vector.

`#include <capflatvolvector.hpp>`

Inheritance diagram for QuantLib::Volatilities::CapFlatVolatilityVector:



Public Methods

- **CapFlatVolatilityVector** (const Date &todaysDate, const Calendar &calendar, int settlementDays, const std::vector< Period > &lengths, const std::vector< double > &volatilities, const DayCounter &dayCounter=DayCounters::Thirty360())
- Date todaysDate () const

  returns today's date.

- Date settlementDate () const

  returns the settlement date.

- DayCounter dayCounter () const

  returns the day counter used for internal date/time conversions.

11.30.1 Detailed Description

This class provides the at-the-money volatility for a given cap by interpolating a volatility vector whose elements are the market volatilities of a set of caps/floors with given length.

Todo:

Either add correct copy behavior or inhibit copy. Right now, a copied instance would end up with its own copy of the length vector but an interpolation pointing to the original ones.

The documentation for this class was generated from the following file:

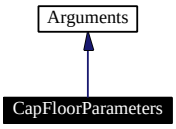
- capflatvolvector.hpp

11.31 QuantLib::Instruments::CapFloorParameters Class Reference

parameters for cap/floor calculation.

`#include <capfloor.hpp>`

Inheritance diagram for QuantLib::Instruments::CapFloorParameters:



Public Methods

- **CapFloorParameters** ()
- void **validate** () const

Public Attributes

- VanillaCapFloor::Type **type**
- std::vector< Time > **startTimes**
- std::vector< Time > **endTimes**
- std::vector< Time > **accrualTimes**
- std::vector< Rate > **capRates**
- std::vector< Rate > **floorRates**
- std::vector< Rate > **forwards**
- std::vector< double > **nominals**

The documentation for this class was generated from the following files:

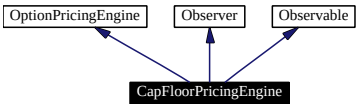
- capfloor.hpp
- capfloor.cpp

11.32 QuantLib::Pricers::CapFloorPricingEngine Class Template Reference

base class for cap/floor pricing engines.

`#include <capfloor.hpp>`

Inheritance diagram for QuantLib::Pricers::CapFloorPricingEngine:



Public Methods

- **CapFloorPricingEngine** ()
- **CapFloorPricingEngine** (const Handle< ModelType > &model)
- Arguments * **parameters** ()
- const Results * **results** () const
- void **validateParameters** () const
- void **setModel** (const Handle< ModelType > &model)
- void update ()

Protected Attributes

- Instruments::CapFloorParameters **parameters_**
- Instruments::CapFloorResults **results_**
- Handle< ModelType > **model_**

11.32.1 Detailed Description

template<class ModelType> class QuantLib::Pricers::CapFloorPricingEngine< ModelType >

Derived engines only need to implement the `calculate()` method

11.32.2 Member Function Documentation

11.32.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

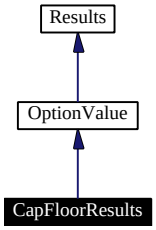
- capfloor.hpp

11.33 QuantLib::Instruments::CapFloorResults Class Reference

results from cap/floor calculation.

`#include <capfloor.hpp>`

Inheritance diagram for QuantLib::Instruments::CapFloorResults:



The documentation for this class was generated from the following file:

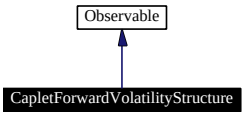
- capfloor.hpp

11.34 QuantLib::CapletForwardVolatilityStructure Class Reference

Caplet/floorlet forward volatility structure.

`#include <capvolstructures.hpp>`

Inheritance diagram for QuantLib::CapletForwardVolatilityStructure:



Public Methods

- virtual ~**CapletForwardVolatilityStructure** ()
- virtual Date todaysDate () const=0

  returns today's date.
- virtual Date settlementDate () const=0

  returns the settlement date.
- virtual DayCounter dayCounter () const=0

  returns the day counter used for internal date/time conversions.
- double volatility (const Date &start, Rate strike) const

  returns the volatility for a given start date and strike rate.
- double volatility (Time t, Rate strike) const

  returns the volatility for a given start time and strike rate.

Protected Methods

- virtual double volatilityImpl (Time length, Rate strike) const=0

  implements the actual volatility calculation in derived classes.

11.34.1 Detailed Description

This class is purely abstract and defines the interface of concrete structures which will be derived from this one.

The documentation for this class was generated from the following file:

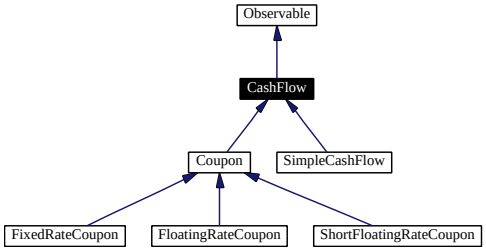
- capvolstructures.hpp

11.35 QuantLib::CashFlow Class Reference

Base class for cash flows.

`#include <cashflow.hpp>`

Inheritance diagram for QuantLib::CashFlow:



Public Methods

- virtual ~**CashFlow** ()
- virtual double amount () const=0

  returns the amount of the cash flow.

- virtual Date date () const=0

  returns the date at which the cash flow is settled.

11.35.1 Detailed Description

This class is purely virtual and acts as a base class for the actual cash flow implementations.

11.35.2 Member Function Documentation

11.35.2.1 virtual double amount () const [pure virtual]

Note:
The amount is not discounted, i.e., it is the actual amount paid at the cash flow date.

Implemented in QuantLib::CashFlows::FixedRateCoupon.

The documentation for this class was generated from the following file:

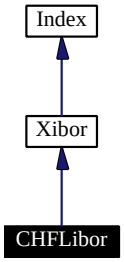
- cashflow.hpp

11.36 QuantLib::Indexes::CHFLibor Class Reference

CHF Libor index (Also known as ZIBOR, check settlement days and day-count).

`#include <chflibor.hpp>`

Inheritance diagram for QuantLib::Indexes::CHFLibor:



Public Methods

- **CHFLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

- chflibor.hpp

11.37 QuantLib::RandomNumbers::CLGaussianRng Class Template Reference

Gaussian random number generator.

`#include <centrallimitgaussianrng.hpp>`

Public Types

- typedef MonteCarlo::Sample< double > **sample_type**

Public Methods

- **CLGaussianRng** (long seed=0)
- sample_type next () const

  returns next sample from the Gaussian distribution.

11.37.1 Detailed Description

template<class U> class QuantLib::RandomNumbers::CLGaussianRng< U >

It uses the well-known fact that the sum of 12 uniform deviate in (-.5,.5) is approximately a Gaussian deviate with average 0 and standard deviation 1. The uniform deviate is supplied by U.

Class U must implement the following interface:

```
U::U(long seed);
U::sample_type U::next() const;
```

The documentation for this class was generated from the following file:

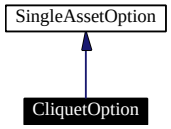
- centrallimitgaussianrng.hpp

11.38 QuantLib::Pricers::CliquetOption Class Reference

cliquet (Ratchet) option.

`#include <cliquetoption.hpp>`

Inheritance diagram for QuantLib::Pricers::CliquetOption:



Public Methods

- **CliquetOption** (Option::Type type, double underlying, Spread dividendYield, Rate riskFreeRate, const std::vector< Time > &dates, double volatility)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- double **vega** () const
- double **rho** () const
- Handle< SingleAssetOption > **clone** () const

11.38.1 Detailed Description

A cliquet option, also known as Ratchet option, is a series of forward-starting options where the strike for the next exercize date is set to the spot price at the beginning of each period. In the particular case in which only two dates are given the price of the option is the same as that of a forward-starting option starting at the first date and expiring at the second date.

The documentation for this class was generated from the following files:

- cliquetoption.hpp
- cliquetoption.cpp

11.39 QuantLib::Utilities::combining_iterator Class Template Reference

Iterator mapping a function to a set of underlying sequences.

`#include <combiningiterator.hpp>`

Public Types

- typedef Function::result_type **value_type**
- typedef const Function::result_type * **pointer**
- typedef const Function::result_type & **reference**

Public Methods

- template<class IteratorCollectionIterator> **combining_iterator** (IteratorCollectionIterator it1, IteratorCollectionIterator it2, Function f)

Dereferencing

- reference **operator** * () const
- pointer **operator** → () const

Random access

- value_type **operator[ ]** (difference_type n) const

Increment and decrement

- combining_iterator & **operator++** ()
- combining_iterator **operator++** (int)
- combining_iterator & **operator–** ()
- combining_iterator **operator–** (int)
- combining_iterator & **operator+=** (difference_type n)
- combining_iterator & **operator-=** (difference_type n)
- combining_iterator **operator+** (difference_type n) const
- combining_iterator **operator-** (difference_type n) const

Difference

- difference_type **operator-** (const combining_iterator< Iterator, Function > &rhs) const

Comparisons

- bool **operator==** (const combining_iterator< Iterator, Function > &rhs) const
- bool **operator!=** (const combining_iterator< Iterator, Function > &rhs) const

Public Attributes

- typedef< Iterator >::difference_type **difference_type**

Related Functions

(Note that these are not member functions.)

- combining_iterator< typename 1< It >::value_type, Function > make_combining_iterator (It it1, It it2, Function f)

  helper function to create combining iterators.

11.39.1 Detailed Description

template<class Iterator, class Function> class QuantLib::Utilities::combining_iterator< Iterator, Function >

This iterator advances a set of underlying iterators and returns the values obtained by applying a function to the sets of values such iterators point to.

This class was implemented based on Christopher Baus and Thomas Becker, *Custom Iterators for the STL*, included in the proceedings of the First Workshop on C++ Template Programming, Erfurt, Germany, 2000 (http://www.oonumerics.org/tmpw00/)

The documentation for this class was generated from the following file:

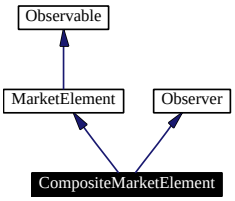
- combiningiterator.hpp

11.40 QuantLib::CompositeMarketElement Class Template Reference

market element whose value depends on two other market element.

`#include <marketelement.hpp>`

Inheritance diagram for QuantLib::CompositeMarketElement:



Public Methods

- **CompositeMarketElement** (const RelinkableHandle< MarketElement > &element1, const RelinkableHandle< MarketElement > &element2, const BinaryFunction &f)

Market element interface

- double value () const

  returns the current value.

Observer interface

- void update ()

template<class BinaryFunction> class QuantLib::CompositeMarketElement< BinaryFunction >

11.40.1 Member Function Documentation

11.40.1.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

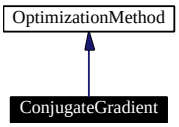
- marketelement.hpp

11.41 QuantLib::Optimization::ConjugateGradient Class Reference

Multi-dimensionnal Conjugate Gradient class.

`#include <conjugategradient.hpp>`

Inheritance diagram for QuantLib::Optimization::ConjugateGradient:



Public Methods

- ConjugateGradient ()
  default constructor.
- **ConjugateGradient** (const Handle< LineSearch > &lineSearch)
- virtual ~ConjugateGradient ()
  destructor.
- virtual void minimize (OptimizationProblem &P)
  minimize the optimization problem P.

11.41.1 Detailed Description

User has to provide line-search method and optimization end criteria

search direction $d_i = -f'(x_i) + c_i * d_{i-1}$ where $c_i = ||f'(x_i)||^2 / ||f'(x_{i-1})||^2$ and $d_1 = -f'(x_1)$

The documentation for this class was generated from the following files:

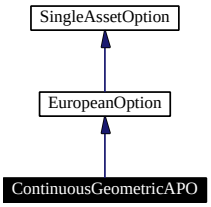
- conjugategradient.hpp
- conjugategradient.cpp

11.42 QuantLib::Pricers::ContinuousGeometricAPO Class Reference

Continuous Geometric Average Price Option (European exercise).

`#include <continuousgeometricapo.hpp>`

Inheritance diagram for QuantLib::Pricers::ContinuousGeometricAPO:



Public Methods

- **ContinuousGeometricAPO** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility)
- double **vega** () const
- double **rho** () const
- Handle< SingleAssetOption > **clone** () const

11.42.1 Detailed Description

This class implements a continuous geometric average price asian option with european exercise. The formula is from "Option Pricing Formulas", E. G. Haug (1997) pag 96-97

Todo:
add Average Strike version and make it backward starting

The documentation for this class was generated from the following file:

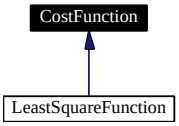
- continuousgeometricapo.hpp

11.43 QuantLib::Optimization::CostFunction Class Reference

Cost function abstract class for optimization problem.

`#include <costfunction.hpp>`

Inheritance diagram for QuantLib::Optimization::CostFunction:



Public Methods

- virtual double value (const Array &x)=0

  method to overload to compute the cost functon value in x.

- virtual void gradient (Array &grad, const Array &x)

  method to overload to compute grad_f, the first derivative of.

- virtual double valueAndGradient (Array &grad, const Array &x)

  method to overload to compute grad_f, the first derivative of.

- virtual double finiteDifferenceEpsilon ()

  Default epsilon for finite difference method :.

The documentation for this class was generated from the following file:

- costfunction.hpp

11.44 QuantLib::Utilities::coupling_iterator Class Template Reference

Iterator mapping a function to a pair of underlying sequences.

`#include <couplingiterator.hpp>`

Public Types

- typedef Function::result_type **value_type**
- typedef const Function::result_type * **pointer**
- typedef const Function::result_type & **reference**

Public Methods

- **coupling_iterator** (Iterator1 it1, Iterator2 it2, Function f)

Dereferencing

- reference **operator** * () const
- pointer **operator** → () const

Random access

- value_type **operator[ ]** (difference_type n) const

Increment and decrement

- coupling_iterator & **operator++** ()
- coupling_iterator **operator++** (int)
- coupling_iterator & **operator–** ()
- coupling_iterator **operator–** (int)
- coupling_iterator & **operator+=** (difference_type n)
- coupling_iterator & **operator-=** (difference_type n)
- coupling_iterator **operator+** (difference_type n) const
- coupling_iterator **operator-** (difference_type n) const

Difference

- difference_type **operator-** (const coupling_iterator &rhs) const

Comparisons

- bool **operator==** (const coupling_iterator &rhs) const
- bool **operator!=** (const coupling_iterator &rhs) const

Public Attributes

- typedef< Iterator1 >::difference_type **difference_type**

Related Functions

(Note that these are not member functions.)

- coupling_iterator< It1, It2, Function > make_coupling_iterator (It1 it1, It2 it2, Function f)
  helper function to create combining iterators.

11.44.1 Detailed Description

template<class Iterator1, class Iterator2, class Function> class QuantLib::Utilities::coupling_iterator< Iterator1, Iterator2, Function >

This iterator advances two underlying iterators and returns the values obtained by applying a function to the two values such iterators point to.

The documentation for this class was generated from the following file:

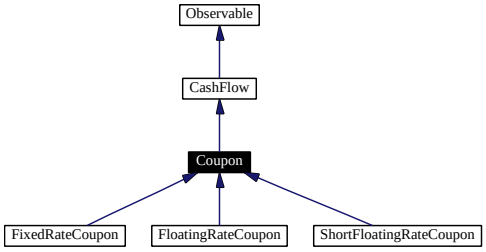
- couplingiterator.hpp

11.45 QuantLib::CashFlows::Coupon Class Reference

coupon accruing over a fixed period.

`#include <coupon.hpp>`

Inheritance diagram for QuantLib::CashFlows::Coupon:



Public Methods

- **Coupon** (double nominal, const Calendar &calendar, RollingConvention rollingConvention, const DayCounter &dayCounter, const Date &startDate, const Date &endDate, const Date &refPeriodStart=Date(), const Date &refPeriodEnd=Date())

Partial CashFlow interface

- Date date () const
  returns the date at which the cash flow is settled.

Inspectors

- double **nominal** () const
- const Date & accrualStartDate () const
  start of the accrual period.
- const Date & accrualEndDate () const
  end of the accrual period.
- Time accrualPeriod () const
  accrual period as fraction of year.
- int accrualDays () const
  accrual period in days.
- virtual double accruedAmount (const Date &) const=0
  accrued amount at the given date.

Protected Attributes

- double **nominal**_
- Date **startDate**_

- Date **endDate_**
- Date **refPeriodStart_**
- Date **refPeriodEnd_**
- Calendar **calendar_**
- RollingConvention **rollingConvention_**
- DayCounter **dayCounter_**

11.45.1 Detailed Description

This class implements part of the CashFlow interface but it is still abstract and provides derived classes with methods for accrual period calculations.

The documentation for this class was generated from the following file:

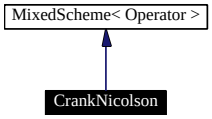
- coupon.hpp

11.46 QuantLib::FiniteDifferences::CrankNicolson Class Template Reference

Crank-Nicolson scheme for finite difference methods.

`#include <cranknicolson.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::CrankNicolson:



Friends

- class **FiniteDifferenceModel**< **CrankNicolson**< **Operator** > >

11.46.1 Detailed Description

template<**class Operator**> **class QuantLib::FiniteDifferences::CrankNicolson**< **Operator** >

See sect. The finite differences framework for details on the method.

In this implementation, the passed operator must be derived from either TimeConstantOperator or TimeDependentOperator. Also, it must implement at least the following interface:

```
typedef ... arrayType;

// copy constructor/assignment
// (these will be provided by the compiler if none is defined)
Operator(const Operator&);
Operator& operator=(const Operator&);

// inspectors
Size size();

// modifiers
void setTime(Time t);

// operator interface
arrayType applyTo(const arrayType&);
arrayType solveFor(const arrayType&);
static Operator identity(Size size);

// operator algebra
Operator operator*(double, const Operator&);
Operator operator+(const Operator&, const Operator&);
Operator operator+(const Operator&, const Operator&);
```

Warning:
The differential operator must be linear for this evolver to work.

The documentation for this class was generated from the following file:

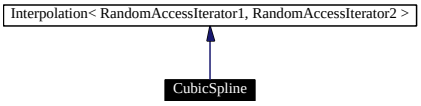
- cranknicolson.hpp

11.47 QuantLib::Math::CubicSpline Class Template Reference

cubic spline interpolation between discrete points.

`#include <cubicspline.hpp>`

Inheritance diagram for QuantLib::Math::CubicSpline:



Public Methods

- **CubicSpline** (const RandomAccessIterator1 &xBegin, const RandomAccessIterator1 &xEnd, const RandomAccessIterator2 &yBegin, bool allowExtrapolation)
- result_type operator() (const argument_type &x) const
- virtual ~**CubicSpline** ()

Public Attributes

- typedef< RandomAccessIterator1 >::value_type **argument_type**
- typedef< RandomAccessIterator2 >::value_type **result_type**

template<class RandomAccessIterator1, class RandomAccessIterator2> class QuantLib::Math::CubicSpline< RandomAccessIterator1, RandomAccessIterator2 >

11.47.1 Member Function Documentation

11.47.1.1 result_type operator() (const argument_type & *x*) const [virtual]

This operator must be overridden to provide an implementation of the actual interpolation.

Precondition:
The sequence of values for x must have been sorted for the result to make sense.

Implements QuantLib::Math::Interpolation.

The documentation for this class was generated from the following file:

- cubicspline.hpp

11.48 QuantLib::CurrencyFormatter Class Reference

Formats currencies for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (Currency c)

The documentation for this class was generated from the following files:

- dataformatters.hpp
- dataformatters.cpp

11.49 QuantLib::Date Class Reference

Concrete date class.

`#include <date.hpp>`

Public Methods

constructors

- Date ()
  Default constructor returning a null date.
- Date (int serialNumber)
  Constructor taking a serial number as given by Applix or Excel.
- Date (Day d, Month m, Year y)
  More traditional constructor.

inspectors

- Weekday **weekday** () const
- Day **dayOfMonth** () const
- Day dayOfYear () const
  One-based (Jan 1st = 1).
- Month **month** () const
- Year **year** () const
- int **serialNumber** () const

date algebra

- Date & operator+= (int days)
  increments date in place.
- Date & operator-= (int days)
  decrement date in place.
- Date & operator++ ()
  1-day pre-increment.
- Date operator++ (int)
  1-day post-increment.
- Date & operator– ()
  1-day pre-decrement.
- Date operator– (int)
  1-day post-decrement.
- Date operator+ (int days) const
  returns a new incremented date.

- Date operator- (int days) const
  returns a new decremented date.

other methods to increment/decrement dates

- Date **plusDays** (int days) const
- Date **plusWeeks** (int weeks) const
- Date **plusMonths** (int months) const
- Date **plusYears** (int years) const
- Date **plus** (int units, TimeUnit) const
- Date **plus** (const Period &) const

Static Public Methods

static methods

- bool **isLeap** (Year y)
- Date minDate ()
  earliest allowed date.
- Date maxDate ()
  latest allowed date.

Related Functions

(Note that these are not member functions.)

- int operator- (const Date &, const Date &)
  Difference in days between dates.
- bool **operator==** (const Date &, const Date &)
- bool **operator!=** (const Date &, const Date &)
- bool **operator**< (const Date &, const Date &)
- bool **operator**<= (const Date &, const Date &)
- bool **operator**> (const Date &, const Date &)
- bool **operator**>= (const Date &, const Date &)
- std::ostream & **operator**<< (std::ostream &stream, const Date &result)

11.49.1 Detailed Description

This class provides methods to inspect dates as well as methods and operators which implement a limited date algebra (increasing and decreasing dates, and calculating their difference).

The documentation for this class was generated from the following files:

- date.hpp
- date.cpp

11.50 QuantLib::DateFormatter Class Reference

Formats dates for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (const Date &d, bool shortFormat=false)

11.50.1 Detailed Description

Formatting can be in short (mm/dd/yyyy) or long (Month ddth, yyyy) form.

The documentation for this class was generated from the following files:

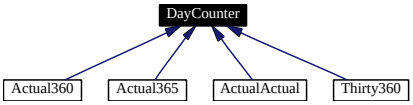
- dataformatters.hpp
- dataformatters.cpp

11.51 QuantLib::DayCounter Class Reference

day counter class.

`#include <daycounter.hpp>`

Inheritance diagram for QuantLib::DayCounter:



Public Methods

DayCounter interface

- std::string name () const
  Returns the name of the day counter.
- int dayCount (const Date &, const Date &) const
  Returns the number of days between two dates.
- Time yearFraction (const Date &, const Date &, const Date &refPeriodStart=Date(), const Date &refPeriodEnd=Date()) const
  Returns the period between two dates as a fraction of year.

Protected Methods

- DayCounter (const Handle< DayCounterImpl > &impl)

Related Functions

(Note that these are not member functions.)

- bool operator== (const DayCounter &, const DayCounter &)
- bool **operator!=** (const DayCounter &, const DayCounter &)

11.51.1 Detailed Description

This class provides methods for determining the length of a time period according to given market convention, both as a number of days and as a year fraction.

The Strategy pattern is used to provide the base behavior of the day counter.

11.51.2 Constructor & Destructor Documentation

11.51.2.1 DayCounter (const Handle< DayCounterImpl > & *impl*) `[inline, protected]`

this protected constructor will only be invoked by derived classes which define a given Calendar implementation

11.51.3 Member Function Documentation

11.51.3.1 std::string name () const [inline]

Warning:
This method is used for output and comparison between day counters. It is **not** meant to be used for writing switch-on-type code.

11.51.4 Friends And Related Function Documentation

11.51.4.1 bool operator== (const DayCounter &, const DayCounter &) [related]

Returns `true` iff the two day counters belong to the same derived class.

The documentation for this class was generated from the following file:

- daycounter.hpp

11.52 QuantLib::DayCounter::DayCounterImpl Class Reference

abstract base class for day counter implementations.

`#include <daycounter.hpp>`

Public Methods

- virtual std::string **name** () const=0
- virtual int **dayCount** (const Date &, const Date &) const=0
- virtual Time **yearFraction** (const Date &, const Date &, const Date &refPeriodStart, const Date &refPeriodEnd) const=0

The documentation for this class was generated from the following file:

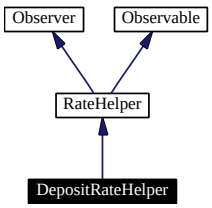
- daycounter.hpp

11.53 QuantLib::TermStructures::DepositRateHelper Class Reference

Deposit rate.

`#include <ratehelpers.hpp>`

Inheritance diagram for QuantLib::TermStructures::DepositRateHelper:



Public Methods

- **DepositRateHelper** (const RelinkableHandle< MarketElement > &rate, int settlementDays, int n, TimeUnit units, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- **DepositRateHelper** (double rate, int settlementDays, int n, TimeUnit units, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- double **impliedQuote** () const
- DiscountFactor **discountGuess** () const
- void setTermStructure (TermStructure *)

  sets the term structure to be used for pricing.

- Date maturity () const

  maturity date.

11.53.1 Detailed Description

Warning:
This class assumes that today's date does not change between calls of setTermStructure().

11.53.2 Member Function Documentation

11.53.2.1 void setTermStructure (TermStructure *) [virtual]

Warning:
Being a pointer and not a Handle, the term structure is not guaranteed to remain allocated for the whole life of the rate helper. It is responsibility of the programmer to ensure that the pointer remains valid. It is advised that rate helpers be used only in term structure constructors, setting the term structure to **this**, i.e., the one being constructed.

Reimplemented from QuantLib::TermStructures::RateHelper.

The documentation for this class was generated from the following files:

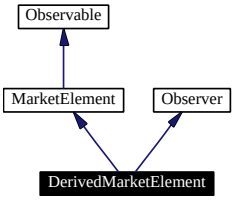
- ratehelpers.hpp
- ratehelpers.cpp

11.54 QuantLib::DerivedMarketElement Class Template Reference

market element whose value depends on another market element.

`#include <marketelement.hpp>`

Inheritance diagram for QuantLib::DerivedMarketElement:



Public Methods

- **DerivedMarketElement** (const RelinkableHandle< MarketElement > &element, const UnaryFunction &f)

Market element interface

- double value () const
  returns the current value.

Observer interface

- void update ()

template<class UnaryFunction> class QuantLib::DerivedMarketElement< UnaryFunction >

11.54.1 Member Function Documentation

11.54.1.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

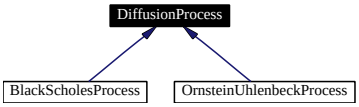
- marketelement.hpp

11.55 QuantLib::DiffusionProcess Class Reference

Diffusion process class.

`#include <diffusionprocess.hpp>`

Inheritance diagram for QuantLib::DiffusionProcess:



Public Methods

- **DiffusionProcess** (double x0)
- virtual ~**DiffusionProcess** ()
- double **x0** () const
- virtual double **drift** (Time t, double x) const=0
- virtual double **diffusion** (Time t, double x) const=0
- virtual double expectation (Time t0, double x0, Time dt) const

  Euler approximation of the expectation.

- virtual double variance (Time t0, double x0, Time dt) const

  Euler approximation of the variance.

11.55.1 Detailed Description

This class describes a stochastic process governed by

$$dx = \mu(t,x)dt + \sigma(t,x)dW_t$$

.

The documentation for this class was generated from the following file:

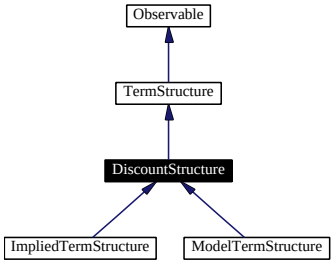
- diffusionprocess.hpp

11.56 QuantLib::DiscountStructure Class Reference

Discount factor term structure.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::DiscountStructure:



Public Methods

- virtual ~**DiscountStructure** ()

Protected Methods

- Rate zeroYieldImpl (Time, bool extrapolate=false) const
- Rate forwardImpl (Time, bool extrapolate=false) const

11.56.1 Detailed Description

This abstract class acts as an adapter to TermStructure allowing the programmer to implement only the `discount(const Date&)` method in derived classes.

11.56.2 Member Function Documentation

11.56.2.1 Rate zeroYieldImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the zero yield rate for the given date calculating it from the discount.

Implements QuantLib::TermStructure.

11.56.2.2 Rate forwardImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the instantaneous forward rate for the given date calculating it from the discount.

Implements QuantLib::TermStructure.

The documentation for this class was generated from the following file:

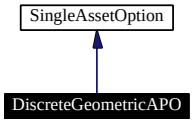
- termstructure.hpp

11.57 QuantLib::Pricers::DiscreteGeometricAPO Class Reference

Discrete Geometric Average Price Asian Option (European style).

`#include <discretegeometricapo.hpp>`

Inheritance diagram for QuantLib::Pricers::DiscreteGeometricAPO:



Public Methods

- **DiscreteGeometricAPO** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, const std::vector< Time > &times, double volatility)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- Handle< SingleAssetOption > **clone** () const

11.57.1 Detailed Description

This class implements a discrete geometric average price asian option, with european exercise. The formula is from "Asian Option", E. Levy (1997) in "Exotic Options: The State of the Art", edited by L. Clewlow, C. Strickland, pag65-97

Todo:
add analytical greeks

The documentation for this class was generated from the following files:

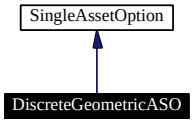
- discretegeometricapo.hpp
- discretegeometricapo.cpp

11.58 QuantLib::Pricers::DiscreteGeometricASO Class Reference

Discrete Geometric Average Strike Asian Option (European style).

`#include <discretegeometricaso.hpp>`

Inheritance diagram for QuantLib::Pricers::DiscreteGeometricASO:



Public Methods

- **DiscreteGeometricASO** (Option::Type type, double underlying, Spread dividendYield, Rate riskFreeRate, const std::vector< Time > &times, double volatility)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- Handle< SingleAssetOption > **clone** () const

11.58.1 Detailed Description

This class implements a discrete geometric average strike asian option, with european exercise. The formula is from "Asian Option", E. Levy (1997) in "Exotic Options: The State of the Art", edited by L. Clewlow, C. Strickland, pag65-97

Todo:
add analytical greeks

The documentation for this class was generated from the following files:

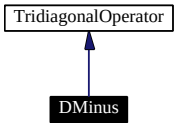
- discretegeometricaso.hpp
- discretegeometricaso.cpp

11.59 QuantLib::FiniteDifferences::DMinus Class Reference

D_- matricial representation.

`#include <dminus.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::DMinus:



Public Methods

- **DMinus** (Size gridPoints, double h)

11.59.1 Detailed Description

The differential operator D_- discretizes the first derivative with the first-order formula

$$\frac{\partial u_i}{\partial x} \approx \frac{u_i - u_{i-1}}{h} = D_- u_i$$

The documentation for this class was generated from the following file:

- dminus.hpp

11.60 QuantLib::DoubleFormatter Class Reference

Formats doubles for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (double x, int precision=6, int digits=0)

11.60.1 Detailed Description

Examples:
DiscreteHedging.cpp.

The documentation for this class was generated from the following files:

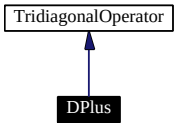
- dataformatters.hpp
- dataformatters.cpp

11.61 QuantLib::FiniteDifferences::DPlus Class Reference

D_+ matricial representation.

`#include <dplus.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::DPlus:



Public Methods

- **DPlus** (Size gridPoints, double h)

11.61.1 Detailed Description

The differential operator D_+ discretizes the first derivative with the first-order formula

$$\frac{\partial u_i}{\partial x} \approx \frac{u_{i+1} - u_i}{h} = D_+ u_i$$

The documentation for this class was generated from the following file:

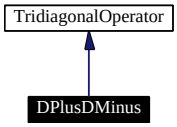
- dplus.hpp

11.62 QuantLib::FiniteDifferences::DPlusDMinus Class Reference

D_+D_- matricial representation.

`#include <dplusdminus.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::DPlusDMinus:



Public Methods

- **DPlusDMinus** (Size gridPoints, double h)

11.62.1 Detailed Description

The differential operator D_+D_- discretizes the second derivative with the second-order formula

$$\frac{\partial^2 u_i}{\partial x^2} \approx \frac{u_{i+1} - 2u_i + u_{i-1}}{h^2} = D_+D_-u_i$$

The documentation for this class was generated from the following file:

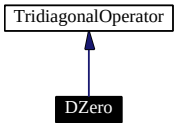
- dplusdminus.hpp

11.63 QuantLib::FiniteDifferences::DZero Class Reference

D_0 matricial representation.

`#include <dzero.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::DZero:



Public Methods

- **DZero** (Size gridPoints, double h)

11.63.1 Detailed Description

The differential operator D_0 discretizes the first derivative with the second-order formula

$$\frac{\partial u_i}{\partial x} \approx \frac{u_{i+1} - u_{i-1}}{2h} = D_0 u_i$$

The documentation for this class was generated from the following file:

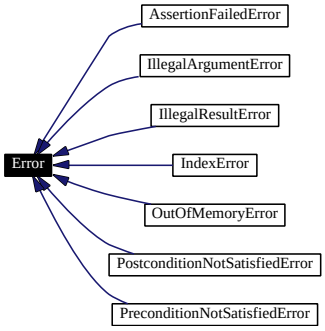
- dzero.hpp

11.64 QuantLib::Error Class Reference

Base error class.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::Error:



Public Methods

- **Error** (const std::string &what="")
- ~**Error** () throw ()
- const char * what () const throw ()

  returns the error message.

The documentation for this class was generated from the following file:

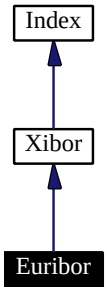
- errors.hpp

11.65 QuantLib::Indexes::Euribor Class Reference

Euribor index.

`#include <euribor.hpp>`

Inheritance diagram for QuantLib::Indexes::Euribor:



Public Methods

- **Euribor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

- euribor.hpp

11.66 QuantLib::EuroFormatter Class Reference

Formats amounts in Euro for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (double amount)

11.66.1 Detailed Description

Formatting follows Euro convention (x,xxx,xxx.xx)

The documentation for this class was generated from the following files:

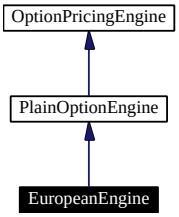
- dataformatters.hpp
- dataformatters.cpp

11.67 QuantLib::Pricers::EuropeanEngine Class Reference

analytic pricing engine for European options.

`#include <europeanengine.hpp>`

Inheritance diagram for QuantLib::Pricers::EuropeanEngine:



Public Methods

- void **calculate** () const

The documentation for this class was generated from the following files:

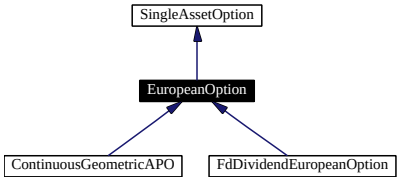
- europeanengine.hpp
- europeanengine.cpp

11.68 QuantLib::Pricers::EuropeanOption Class Reference

Black-Scholes-Merton European option.

`#include <europeanoption.hpp>`

Inheritance diagram for QuantLib::Pricers::EuropeanOption:



Public Methods

- **EuropeanOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility)
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- double **vega** () const
- double **rho** () const
- double **dividendRho** () const
- Handle< SingleAssetOption > **clone** () const
- void **setVolatility** (double newVolatility)
- void **setRiskFreeRate** (Rate newRate)
- void **setDividendYield** (Rate newDividendYield)

11.68.1 Detailed Description

Examples:
DiscreteHedging.cpp, and EuropeanOption.cpp.

The documentation for this class was generated from the following files:

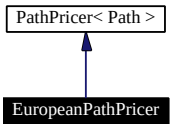
- europeanoption.hpp
- europeanoption.cpp

11.69 QuantLib::MonteCarlo::EuropeanPathPricer Class Reference

path pricer for European options.

`#include <europeanpathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::EuropeanPathPricer:



Public Methods

- **EuropeanPathPricer** (Option::Type type, double underlying, double strike, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const Path &path) const

The documentation for this class was generated from the following files:

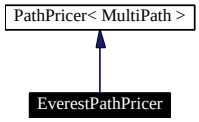
- europeanpathpricer.hpp
- europeanpathpricer.cpp

11.70 QuantLib::MonteCarlo::EverestPathPricer Class Reference

path pricer for European-type Everest option.

`#include <everestpathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::EverestPathPricer:



Public Methods

- **EverestPathPricer** (DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const MultiPath &multiPath) const

11.70.1 Detailed Description

The payoff of an Everest option is given by the final-price initial-price ratio of the worst performer.

The documentation for this class was generated from the following files:

- everestpathpricer.hpp
- everestpathpricer.cpp

11.71 QuantLib::Exercise Class Reference

Exercise class (American, Bermudan or European).

`#include <exercise.hpp>`

Public Types

- enum **Type** { **American**, **Bermudan**, **European** }

Public Methods

- **Exercise** (Type type, const std::vector< Date > &dates)
- Type **type** () const
- Date **date** (Size index=0) const
- const std::vector< Date > & **dates** () const
- RollingConvention **rollingConvention** () const
- Calendar **calendar** () const
- int **settlementDays** () const

Protected Attributes

- Type **type_**
- std::vector< Date > **dates_**
- Calendar **calendar_**
- RollingConvention **convention_**
- int **settlementDays_**

The documentation for this class was generated from the following file:

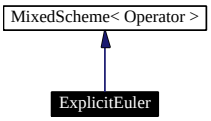
- exercise.hpp

11.72 QuantLib::FiniteDifferences::ExplicitEuler Class Template Reference

Forward Euler scheme for finite difference methods.

`#include <expliciteuler.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::ExplicitEuler:



Friends

- class **FiniteDifferenceModel**< **ExplicitEuler**< **Operator** > >

11.72.1 Detailed Description

template<**class Operator**> **class QuantLib::FiniteDifferences::ExplicitEuler**< **Operator** >

See sect. The finite differences framework for details on the method.

In this implementation, the passed operator must be derived from either TimeConstantOperator or TimeDependentOperator. Also, it must implement at least the following interface:

```
typedef ... arrayType;

// copy constructor/assignment
// (these will be provided by the compiler if none is defined)
Operator(const Operator&);
Operator& operator=(const Operator&);

// inspectors
Size size();

// modifiers
void setTime(Time t);

// operator interface
arrayType applyTo(const arrayType&);
static Operator identity(Size size);

// operator algebra
Operator operator*(double, const Operator&);
Operator operator-(const Operator&, const Operator&);
```

Todo:
add Richardson extrapolation

The documentation for this class was generated from the following file:

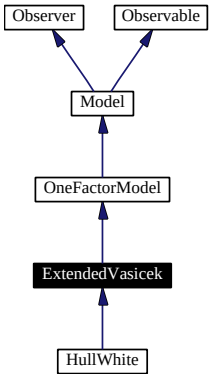
- expliciteuler.hpp

11.73 QuantLib::InterestRateModelling::ExtendedVasicek Class Reference

Extended Vasicek model class.

`#include <hullwhite.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::ExtendedVasicek:



Public Methods

- **ExtendedVasicek** (const Parameter &a, const Parameter &sigma, const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**ExtendedVasicek** ()
- virtual Handle< Lattices::Tree > tree (const TimeGrid &grid) const

  Return a recombining tree.

- virtual Handle< ShortRateProcess > process () const

  returns the driving stochastic equation.

Protected Methods

- virtual void **generateParameters** ()

Protected Attributes

- Parameter & **a**_
- Parameter & **sigma**_
- Parameter & **phi**_

11.73.1 Detailed Description

This class implements the extended Vasicek model defined by

$$dr_t = (\theta(t) - \alpha(t)r_t)dt + \sigma(t)dW_t.$$

It is actually implemented as $r_t = x_t + \varphi(t)$ where x_t is defined by

$$dx_t = -\alpha(t)r_t dt + \sigma(t)dW_t$$

The documentation for this class was generated from the following file:

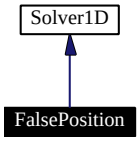
- hullwhite.hpp

11.74 QuantLib::Solvers1D::FalsePosition Class Reference

False position 1-D solver.

`#include <falseposition.hpp>`

Inheritance diagram for QuantLib::Solvers1D::FalsePosition:



The documentation for this class was generated from the following files:

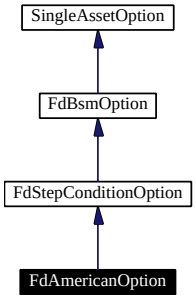
- falseposition.hpp
- falseposition.cpp

11.75 QuantLib::Pricers::FdAmericanOption Class Reference

American option.

`#include <fdamericanoption.hpp>`

Inheritance diagram for QuantLib::Pricers::FdAmericanOption:



Public Methods

- **FdAmericanOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, int timeSteps, int gridPoints)
- void **initializeStepCondition** () const
- Handle< SingleAssetOption > **clone** () const

11.75.1 Detailed Description

Todo:

make american call with no dividens = european

The documentation for this class was generated from the following file:

- fdamericanoption.hpp

11.76 QuantLib::Pricers::FdBermudanOption Class Reference

Bermudan option.

`#include <fdbermudanoption.hpp>`

Public Methods

- **FdBermudanOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, const std::vector< Time > &dates=std::vector< Time >(), int timeSteps=100, int gridPoints=100)
- Handle< SingleAssetOption > **clone** () const

Protected Methods

- void **initializeStepCondition** () const
- void **executeIntermediateStep** (int) const

Protected Attributes

- double **extraTermInBermudan**

The documentation for this class was generated from the following files:

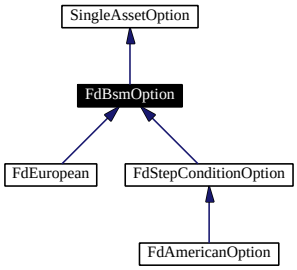
- fdbermudanoption.hpp
- fdbermudanoption.cpp

11.77 QuantLib::Pricers::FdBsmOption Class Reference

Black-Scholes-Merton option priced numerically.

`#include <fdbsmoption.hpp>`

Inheritance diagram for QuantLib::Pricers::FdBsmOption:



Public Methods

- **FdBsmOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, Size gridPoints)
- virtual void **calculate** () const=0
- double **value** () const
- double **delta** () const
- double **gamma** () const
- double **theta** () const
- Array **getGrid** () const

Protected Methods

- virtual void **setGridLimits** (double center, double timeDelay) const
- virtual void **initializeGrid** () const
- virtual void **initializeInitialCondition** () const
- virtual void **initializeOperator** () const

Protected Attributes

- Size **gridPoints_**
- double **value_**
- double **delta_**
- double **gamma_**
- double **theta_**
- Array **grid_**
- FiniteDifferences::BSMOperator **finiteDifferenceOperator_**
- Array **initialPrices_**
- double **sMin_**
- double **center_**
- double **sMax_**

The documentation for this class was generated from the following files:

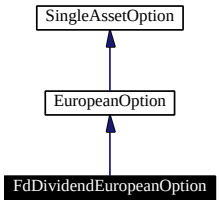
- fdbsmoption.hpp
- fdbsmoption.cpp

11.78 QuantLib::Pricers::FdDividendEuropeanOption Class Reference

European option with dividends.

`#include <fddividendeuropeanoption.hpp>`

Inheritance diagram for QuantLib::Pricers::FdDividendEuropeanOption:



Public Methods

- **FdDividendEuropeanOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, const std::vector< double > &dividends, const std::vector< Time > &exdivdates)
- double **theta** () const
- double **rho** () const
- double **dividendRho** () const
- Handle< SingleAssetOption > **clone** () const

The documentation for this class was generated from the following files:

- fddividendeuropeanoption.hpp
- fddividendeuropeanoption.cpp

11.79 QuantLib::Pricers::FdDividendShoutOption Class Reference

Shout option with dividends.

`#include <fddividendshoutoption.hpp>`

Public Methods

- **FdDividendShoutOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, const std::vector< double > &dividends=std::vector< double >(), const std::vector< Time > &exdivdates=std::vector< Time >(), int timeSteps=100, int gridPoints=100)
- Handle< SingleAssetOption > **clone** () const
- double **dividendRho** () const

Protected Methods

- void **initializeStepCondition** () const

The documentation for this class was generated from the following files:

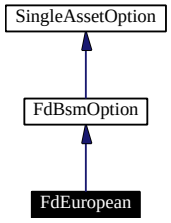
- fddividendshoutoption.hpp
- fddividendshoutoption.cpp

11.80 QuantLib::Pricers::FdEuropean Class Reference

Example of European option calculated using finite differences.

`#include <fdeuropean.hpp>`

Inheritance diagram for QuantLib::Pricers::FdEuropean:



Public Methods

- **FdEuropean** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, Size timeSteps=200, Size gridPoints=800)
- Array **getPrices** () const
- Handle< SingleAssetOption > **clone** () const

Protected Methods

- void **calculate** () const

11.80.1 Detailed Description

Examples:
EuropeanOption.cpp.

The documentation for this class was generated from the following files:

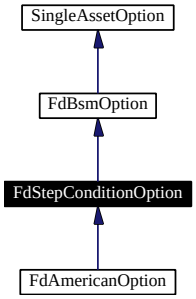
- fdeuropean.hpp
- fdeuropean.cpp

11.81 QuantLib::Pricers::FdStepConditionOption Class Reference

option executing additional code at each time step.

`#include <fdstepconditionoption.hpp>`

Inheritance diagram for QuantLib::Pricers::FdStepConditionOption:



Protected Methods

- **FdStepConditionOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility, int timeSteps, int gridPoints)
- void **calculate** () const
- virtual void **initializeStepCondition** () const=0

Protected Attributes

- Handle< FiniteDifferences::StandardStepCondition > **stepCondition_**
- int **timeSteps_**

The documentation for this class was generated from the following files:

- fdstepconditionoption.hpp
- fdstepconditionoption.cpp

11.82 QuantLib::Utilities::filtering_iterator Class Template Reference

Iterator filtering undesired data.

`#include <filteringiterator.hpp>`

Public Methods

- **filtering_iterator** (const Iterator &, const UnaryPredicate &, const Iterator &beforeBegin, const Iterator &end)

Dereferencing

- reference **operator** * () const
- pointer **operator** → () const

Increment and decrement

- filtering_iterator & **operator++** ()
- filtering_iterator **operator++** (int)
- filtering_iterator & **operator–** ()
- filtering_iterator **operator–** (int)

Comparisons

- bool **operator==** (const filtering_iterator< Iterator, UnaryPredicate > &)
- bool **operator!=** (const filtering_iterator< Iterator, UnaryPredicate > &)

Public Attributes

- typedef< Iterator >::pointer **pointer**
- typedef< Iterator >::reference **reference**

Related Functions

(Note that these are not member functions.)

- filtering_iterator< Iterator, UnaryPredicate > make_filtering_iterator (Iterator it, UnaryPredicate p, Iterator beforeBegin, Iterator end)

  helper function to create filtering iterators.

11.82.1 Detailed Description

template<class Iterator, class UnaryPredicate> class QuantLib::Utilities::filtering_iterator< Iterator, UnaryPredicate >

This iterator advances an underlying iterator returning only those data satisfying a given condition.

The documentation for this class was generated from the following file:

- filteringiterator.hpp

11.83 QuantLib::FiniteDifferences::FiniteDifferenceModel Class Template Reference

Generic finite difference model.

`#include <finitedifferencemodel.hpp>`

Public Types

- typedef Evolver::arrayType **arrayType**
- typedef Evolver::operatorType **operatorType**

Public Methods

- **FiniteDifferenceModel** (const operatorType &L)
- void rollback (arrayType &a, Time from, Time to, Size steps, Handle< StepCondition< arrayType > > condition=Handle< StepCondition< arrayType > >())

11.83.1 Detailed Description

template<class Evolver> class QuantLib::FiniteDifferences::FiniteDifferenceModel< Evolver >

See sect. The finite differences framework

11.83.2 Member Function Documentation

11.83.2.1 void rollback (arrayType & *a*, Time *from*, Time *to*, Size *steps*, Handle< StepCondition< arrayType > > *condition* = Handle< StepCondition< arrayType > >())

solves the problem between the given times, possibly applying a condition at every step.

Warning:
being this a rollback, `from` must be a later time than `to`.

The documentation for this class was generated from the following file:

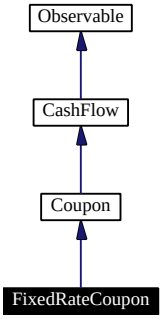
- finitedifferencemodel.hpp

11.84 QuantLib::CashFlows::FixedRateCoupon Class Reference

coupon paying a fixed interest rate.

`#include <fixedratecoupon.hpp>`

Inheritance diagram for QuantLib::CashFlows::FixedRateCoupon:



Public Methods

- **FixedRateCoupon** (double nominal, Rate rate, const Calendar &calendar, RollingConvention rollingConvention, const DayCounter &dayCounter, const Date &startDate, const Date &endDate, const Date &refPeriodStart=Date(), const Date &refPeriodEnd=Date())

CashFlow interface

- double amount () const
  returns the amount of the cash flow.

Coupon interface

- double accruedAmount (const Date &) const
  accrued amount at the given date.

Inspectors

- Rate **rate** () const

11.84.1 Member Function Documentation

11.84.1.1 double amount () const `[inline, virtual]`

Note:
The amount is not discounted, i.e., it is the actual amount paid at the cash flow date.

Implements QuantLib::CashFlow.

The documentation for this class was generated from the following file:

- fixedratecoupon.hpp

11.85 QuantLib::CashFlows::FixedRateCouponVector Class Reference

helper class building a sequence of fixed rate coupons.

`#include <cashflowvectors.hpp>`

Public Methods

- **FixedRateCouponVector** (const std::vector< double > &nominals, const std::vector< Rate > &couponRates, const Date &startDate, const Date &endDate, int frequency, const Calendar &calendar, RollingConvention rollingConvention, bool isAdjusted, const DayCounter &dayCount, const DayCounter &firstPeriodDayCount, const Date &stubDate=Date())

The documentation for this class was generated from the following files:

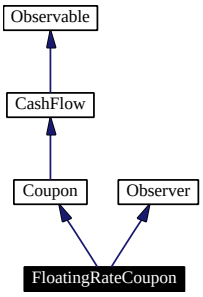
- cashflowvectors.hpp
- cashflowvectors.cpp

11.86 QuantLib::CashFlows::FloatingRateCoupon Class Reference

coupon at par on a term structure.

`#include <floatingratecoupon.hpp>`

Inheritance diagram for QuantLib::CashFlows::FloatingRateCoupon:



Public Methods

- **FloatingRateCoupon** (double nominal, const Handle< Indexes::Xibor > &index, const RelinkableHandle< TermStructure > &termStructure, const Date &startDate, const Date &endDate, int fixingDays, Spread spread=0.0, const Date &refPeriodStart=Date(), const Date &refPeriodEnd=Date())

CashFlow interface

- double amount () const
  returns the amount of the cash flow.

Coupon interface

- double accruedAmount (const Date &) const
  accrued amount at the given date.

Inspectors

- const Handle< Indexes::Xibor > & **index** () const
- int **fixingDays** () const
- Rate **fixing** () const
- Spread **spread** () const

Observer interface

- void update ()

11.86.1 Detailed Description

Warning:
This class does not perform any date adjustment, i.e., the start and end date passed upon construction should be already rolled to a business day.

11.86.2 Member Function Documentation

11.86.2.1 double amount () const [virtual]

Note:
The amount is not discounted, i.e., it is the actual amount paid at the cash flow date.

Implements QuantLib::CashFlow.

11.86.2.2 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following files:

- floatingratecoupon.hpp
- floatingratecoupon.cpp

11.87 QuantLib::CashFlows::FloatingRateCouponVector Class Reference

helper class building a sequence of floating rate coupons.

`#include <cashflowvectors.hpp>`

Public Methods

- **FloatingRateCouponVector** (const std::vector< double > &nominals, const Date &startDate, const Date &endDate, int frequency, const Calendar &calendar, RollingConvention rollingConvention, const RelinkableHandle< TermStructure > &termStructure, const Handle< Indexes::Xibor > &index, int fixingDays, const std::vector< Spread > &spreads=std::vector< Spread >(), const Date &stubDate=Date())

11.87.1 Detailed Description

Warning:
The passing of a non-null stub date - i.e., the creation of a short/long first coupon - is currently disabled.

Todo:
A suitable algorithm should be implemented for the calculation of the interpolated index fixing for a short/long first coupon.

The documentation for this class was generated from the following file:

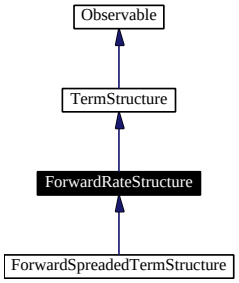
- cashflowvectors.hpp

11.88 QuantLib::ForwardRateStructure Class Reference

Forward rate term structure.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::ForwardRateStructure:



Public Methods

- virtual ~**ForwardRateStructure** ()

Protected Methods

- Rate zeroYieldImpl (Time, bool extrapolate=false) const
- DiscountFactor discountImpl (Time, bool extrapolate=false) const

11.88.1 Detailed Description

This abstract class acts as an adapter to TermStructure allowing the programmer to implement only the `forward(const Date&)` method in derived classes.

11.88.2 Member Function Documentation

11.88.2.1 Rate zeroYieldImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the zero yield rate for the given date calculating it from the instantaneous forward rate.

Warning:
This is just a default, highly inefficient implementation. Derived classes should implement their own zeroYield method.

Implements QuantLib::TermStructure.

Reimplemented in QuantLib::ForwardSpreadedTermStructure.

11.88.2.2 DiscountFactor discountImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the discount factor for the given date calculating it from the instantaneous forward rate.

Implements QuantLib::TermStructure.

The documentation for this class was generated from the following file:

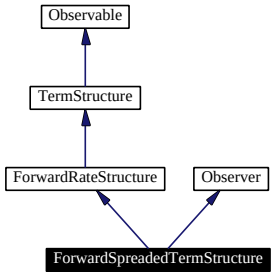
- termstructure.hpp

11.89 QuantLib::ForwardSpreadedTermStructure Class Reference

Term structure with an added spread on the instantaneous forward rate.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::ForwardSpreadedTermStructure:



Public Methods

- **ForwardSpreadedTermStructure** (const RelinkableHandle< TermStructure > &, const RelinkableHandle< MarketElement > &spread)

TermStructure interface

- Currency currency () const
  returns the currency upon which the term structure is defined.
- Date todaysDate () const
  returns today's date.
- int settlementDays () const
  returns the number of settlement days.
- Calendar calendar () const
  returns the calendar for settlement calculation.
- DayCounter dayCounter () const
  returns the day counter.
- Date settlementDate () const
  returns the settlement date.
- Date maxDate () const
  returns the latest date for which the curve can return rates.
- Date minDate () const
  returns the earliest date for which the curve can return rates.
- Time maxTime () const
  returns the latest date for which the curve can return rates.
- Time minTime () const

returns the earliest time for which the curve can return rates.

Observer interface

- void update ()

Protected Methods

- Rate forwardImpl (Time, bool extrapolate=false) const

  returns the spreaded forward rate.

- Rate zeroYieldImpl (Time, bool extrapolate=false) const

  returns the spreaded zero yield rate.

11.89.1 Detailed Description

Note:

This term structure will remain linked to the original structure, i.e., any changes in the latter will be reflected in this structure as well.

11.89.2 Member Function Documentation

11.89.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

11.89.2.2 Rate zeroYieldImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Warning:

This method must disappear should the spread become a curve

Reimplemented from QuantLib::ForwardRateStructure.

The documentation for this class was generated from the following file:

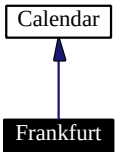
- termstructure.hpp

11.90 QuantLib::Calendars::Frankfurt Class Reference

Frankfurt calendar.

`#include <frankfurt.hpp>`

Inheritance diagram for QuantLib::Calendars::Frankfurt:



Public Methods

- **Frankfurt** ()

11.90.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Good Friday
- Easter Monday
- Ascension Thursday
- Whit Monday
- Corpus Christi
- Labour Day, May 1st
- National Day, October 3rd
- Christmas Eve, December 24th
- Christmas, December 25th
- Boxing Day, December 26th
- New Year's Eve, December 31st

The documentation for this class was generated from the following file:

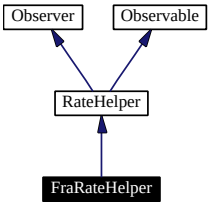
- frankfurt.hpp

11.91 QuantLib::TermStructures::FraRateHelper Class Reference

Forward rate agreement.

`#include <ratehelpers.hpp>`

Inheritance diagram for QuantLib::TermStructures::FraRateHelper:



Public Methods

- **FraRateHelper** (const RelinkableHandle< MarketElement > &rate, int settlementDays, int monthsToStart, int monthsToEnd, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- **FraRateHelper** (double rate, int settlementDays, int monthsToStart, int monthsToEnd, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- double **impliedQuote** () const
- DiscountFactor **discountGuess** () const
- void setTermStructure (TermStructure *)

  sets the term structure to be used for pricing.

- Date maturity () const

  maturity date.

11.91.1 Detailed Description

Warning:
This class assumes that today's date does not change between calls of setTermStructure().

Todo:
convexity adjustment should be implemented.

11.91.2 Member Function Documentation

11.91.2.1 void setTermStructure (TermStructure *) [virtual]

Warning:
Being a pointer and not a Handle, the term structure is not guaranteed to remain allocated for the whole life of the rate helper. It is responsibility of the programmer to ensure that the pointer remains valid. It is advised that rate helpers be used only in term structure constructors, setting the term structure to **this**, i.e., the one being constructed.

Reimplemented from QuantLib::TermStructures::RateHelper.

The documentation for this class was generated from the following files:

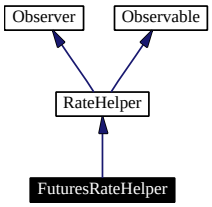
- ratehelpers.hpp
- ratehelpers.cpp

11.92 QuantLib::TermStructures::FuturesRateHelper Class Reference

Interest Rate Futures.

`#include <ratehelpers.hpp>`

Inheritance diagram for QuantLib::TermStructures::FuturesRateHelper:



Public Methods

- **FuturesRateHelper** (const RelinkableHandle< MarketElement > &price, const Date &ImmDate, int settlementDays, int nMonths, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- **FuturesRateHelper** (double price, const Date &ImmDate, int settlementDays, int nMonths, const Calendar &calendar, RollingConvention convention, const DayCounter &dayCounter)
- double **impliedQuote** () const
- DiscountFactor **discountGuess** () const
- Date maturity () const

  maturity date.

11.92.1 Detailed Description

Warning:

This class assumes that today's date does not change between calls of setTermStructure().

The documentation for this class was generated from the following files:

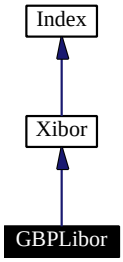
- ratehelpers.hpp
- ratehelpers.cpp

11.93 QuantLib::Indexes::GBPLibor Class Reference

GBP Libor index.

`#include <gbplibor.hpp>`

Inheritance diagram for QuantLib::Indexes::GBPLibor:



Public Methods

- **GBPLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

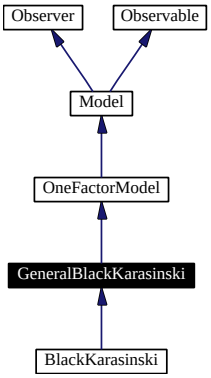
- gbplibor.hpp

11.94 QuantLib::InterestRateModelling::GeneralBlackKarasinski Class Reference

General Black-Karasinski model class.

`#include <blackkarasinski.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::GeneralBlackKarasinski:



Public Methods

- **GeneralBlackKarasinski** (const Parameter &a, const Parameter &sigma, const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**GeneralBlackKarasinski** ()
- virtual Handle< ShortRateProcess > process () const

  returns the driving stochastic equation.

- virtual Handle< Lattices::Tree > tree (const TimeGrid &grid) const

  Return a recombining tree.

Protected Methods

- virtual void **generateParameters** ()

Protected Attributes

- Parameter & **a**_
- Parameter & **sigma**_
- Parameter & **f**_

11.94.1 Detailed Description

This class implements the general Black-Karasinski model defined by

$$d\ln r_t = (\theta(t) - \alpha(t)\ln r_t)dt + \sigma(t)dW_t.$$

It is actually implemented as $r_t = e^{x_t+\varphi(t)}$ where x_t is defined by

$$dx_t = -\alpha(t)r_t dt + \sigma(t)dW_t.$$

The documentation for this class was generated from the following file:

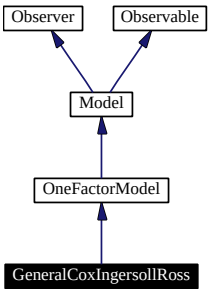
- blackkarasinski.hpp

11.95 QuantLib::InterestRateModelling::GeneralCoxIngersollRoss Class Reference

General single-factor extended Cox-Ingersoll-Ross model class.

`#include <coxingersollross.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::GeneralCoxIngersollRoss:



Public Methods

- **GeneralCoxIngersollRoss** (const Parameter &theta, const Parameter &k, const Parameter &sigma, const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**GeneralCoxIngersollRoss** ()
- virtual Handle< Lattices::Tree > tree (const TimeGrid &grid) const

  Return a recombining tree.

- virtual Handle< ShortRateProcess > process () const

  returns the driving stochastic equation.

Protected Methods

- virtual void **generateParameters** ()

Protected Attributes

- Parameter & **theta**_
- Parameter & **k**_
- Parameter & **sigma**_
- Parameter & **phi**_
- double **x0**_

11.95.1 Detailed Description

This class implements the extended Cox-Ingersoll-Ross model defined by

$$dr_t = (\theta(t) - \alpha(t)r_t)dt + \sqrt{r_t}\sigma(t)dW_t.$$

It is actually implemented as $r_t = \varphi(t) + y_t^2$ where y_t is defined by

$$dy_t = \left[(\frac{k\theta}{2} + \frac{\sigma^2}{8}) \frac{1}{y_t} - \frac{k}{2} y_t \right] d_t + \frac{\sigma}{2} dW_t$$

The documentation for this class was generated from the following file:

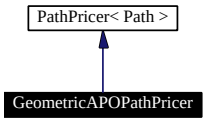
- coxingersollross.hpp

11.96 QuantLib::MonteCarlo::GeometricAPOPathPricer Class Reference

path pricer for geometric average price option.

`#include <geometricapopathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::GeometricAPOPathPricer:



Public Methods

- **GeometricAPOPathPricer** (Option::Type type, double underlying, double strike, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const Path &path) const

The documentation for this class was generated from the following files:

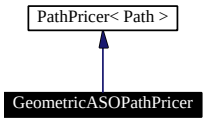
- geometricapopathpricer.hpp
- geometricapopathpricer.cpp

11.97 QuantLib::MonteCarlo::GeometricASOPathPricer Class Reference

path pricer for geometric average price option.

`#include <geometricasopathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::GeometricASOPathPricer:



Public Methods

- **GeometricASOPathPricer** (Option::Type type, double underlying, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const Path &path) const

The documentation for this class was generated from the following files:

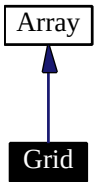
- geometricasopathpricer.hpp
- geometricasopathpricer.cpp

11.98 QuantLib::Grid Class Reference

spatial grid class.

`#include <grid.hpp>`

Inheritance diagram for QuantLib::Grid:



Public Methods

- **Grid** (double center, double dx, Size steps)

The documentation for this class was generated from the following file:

- grid.hpp

11.99 QuantLib::Handle Class Template Reference

Reference-counted pointer.

`#include <handle.hpp>`

Public Methods

constructors, destructor, and assignment

- Handle (T *ptr=0, bool owns=true)
  Constructor taking a pointer.
- template<class U> **Handle** (const Handle< U > &from)
- **Handle** (const Handle &from)
- ~**Handle** ()
- template<class U> Handle & **operator=** (const Handle< U > &from)
- Handle & **operator=** (const Handle &from)

Dereferencing

- T & **operator** * () const
- T * **operator** -> () const

Inspectors

- bool isNull () const
  Checks if the contained pointer is actually allocated.
- bool shareSameObject (const Handle< T > &) const
  Checks if the two handles point to the same object.

Friends

- class **HandleCopier**

11.99.1 Detailed Description

template<class T> class QuantLib::Handle< T >

This class acts as a proxy to a pointer contained in it. Such pointer is owned by the handle, i.e., the handle will be responsible for its deletion, unless explicitly stated by the programmer.

A count of the references to the contained pointer is incremented every time a handle is copied, and decremented every time a handle is deleted or goes out of scope. When the handle owns the pointer, this mechanism ensures on one hand, that the pointer will not be deallocated as long as a handle refers to it, and on the other hand, that it will be deallocated when no more handles do.

Note:
The implementation of this class was originally taken from "The C++ Programming Language", 3rd ed., B.Stroustrup, Addison-Wesley, 1997.

Warning:
This mechanism will break and result in untimely deallocation of the pointer (and very possible death of your executable) if two handles are explicitly initialized with the same pointer, as in

```
SomeObj* so = new SomeObj;
Handle<SomeObj> h1(so);
Handle<SomeObj> h2 = h1;    // this is safe.
Handle<SomeObj> h3(so);     // this is definitely not.
```

It is good practice to create the pointer and immediately pass it to the handle, as in

```
Handle<SomeObj> h1(new SomeObj);    // this is as safe as can be.
```

Warning:
When the programmer keeps the ownership of the pointer, as explicitly declared in

```
SomeObj so;
Handle<SomeObj> h(&so,false);
```

it is responsibility of the programmer to make sure that the object remain in scope as long as there are handles pointing to it. Also, the programmer must explicitly delete the object if required.

Examples:
DiscreteHedging.cpp.

11.99.2 Constructor & Destructor Documentation

11.99.2.1 Handle (T * *ptr* = 0, bool *owns* = true) [inline, explicit]

If **owns** is set to `true` (the default), the handle will be responsible for the deletion of the pointer. If it is set to `false`, the programmer must make sure that the pointed object remains in scope for the lifetime of the handle and its copies. Destruction of the object is also responsibility of the programmer.

It is advised that handles be used with `owns = false` only in a controlled an self-contained environment. Such a case happens when an object needs to pass a handle to itself to inner classes or bootstrappers - i.e., contained or temporary objects whose lifetime is guaranteed not to last more than the lifetime of the object.

The documentation for this class was generated from the following file:

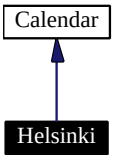
- handle.hpp

11.100 QuantLib::Calendars::Helsinki Class Reference

Helsinki calendar.

`#include <helsinki.hpp>`

Inheritance diagram for QuantLib::Calendars::Helsinki:



Public Methods

- **Helsinki** ()

11.100.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Epiphany, January 6th
- Good Friday
- Easter Monday
- Ascension Thursday
- Labour Day, May 1st
- Midsummer Eve, June 21st
- Independence Day, December 6th
- Christmas Eve, December 24th
- Christmas, December 25th
- Boxing Day, December 26th

Note:
The holiday rules for Wellington were documented by Veli-Pekka Mattila for IDB (`http://www.jrefinery.com/ibd/`)

The documentation for this class was generated from the following file:

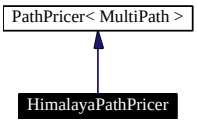
- helsinki.hpp

11.101 QuantLib::MonteCarlo::HimalayaPathPricer Class Reference

multipath pricer for European-type Himalaya option.

`#include <himalayapathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::HimalayaPathPricer:



Public Methods

- **HimalayaPathPricer** (const Array &underlying, double strike, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const MultiPath &multiPath) const

11.101.1 Detailed Description

The payoff of an himalaya option is computed in the following way: given a basket of N assets, and M time periods, at end of each period the option who performed the best is added to the average and then discarded from the basket. At the end of the M periods the option pays the max between the strike and the average of the best performers.

The documentation for this class was generated from the following files:

- himalayapathpricer.hpp
- himalayapathpricer.cpp

11.102 QuantLib::History Class Reference

Container for historical data.

`#include <history.hpp>`

Public Types

- typedef Utilities::filtering_iterator< const_iterator, DataValidator > const_valid_iterator
  bidirectional iterator on non-null history entries.
- typedef std::vector< double >::const_iterator const_data_iterator
  random access iterator on historical data.
- typedef Utilities::filtering_iterator< const_data_iterator, DataValidator > const_valid_data_iterator
  bidirectional iterator on non-null historical data.

Public Methods

- History ()
- template<class Iterator> History (const Date &firstDate, const Date &lastDate, Iterator begin, Iterator end)
- **History** (const Date &firstDate, const std::vector< double > &values)
- History (const Date &firstDate, const Date &lastDate, const std::vector< double > &values)
- History (const std::vector< Date > &dates, const std::vector< double > &values)

Inspectors

- const Date & firstDate () const
  returns the first date for which a historical datum exists.
- const Date & lastDate () const
  returns the last date for which a historical datum exists.
- int size () const
  returns the number of historical data including null ones.

Historical data access

- double operator[ ] (const Date &) const
  returns the (possibly null) datum corresponding to the given date.

Iterator access

Four different types of iterators are provided, namely, const_iterator, const_valid_iterator, const_data_iterator, and const_valid_data_iterator.

const_iterator and const_valid_iterator point to an Entry structure, the difference being that the latter only iterates over valid entries - i.e., entries whose data are not null. The same difference exists between const_data_iterator and const_valid_data_iterator which point directly to historical values without reference to the date they are associated to.

- const_iterator **begin** () const
- const_iterator **end** () const
- const_iterator **iterator** (const Date &d) const
- const_valid_iterator **vbegin** () const
- const_valid_iterator **vend** () const
- const_valid_iterator **valid_iterator** (const Date &d) const
- const_data_iterator **dbegin** () const
- const_data_iterator **dend** () const
- const_data_iterator **data_iterator** (const Date &d) const
- const_valid_data_iterator **vdbegin** () const
- const_valid_data_iterator **vdend** () const
- const_valid_data_iterator **valid_data_iterator** (const Date &d) const

11.102.1 Detailed Description

This class acts as a generic repository for a set of historical data. Single data can be accessed through their date, while sets of consecutive data can be accessed through iterators.

A history can contain null data, which can either be returned or skipped according to the chosen iterator type.

Example: uses of history iterators

11.102.2 Constructor & Destructor Documentation

11.102.2.1 History () [inline]

Default constructor

11.102.2.2 History (const Date & *firstDate*, const Date & *lastDate*, Iterator *begin*, Iterator *end*) [inline]

This constructor initializes the history with the given set of values, corresponding to the date range between ***firstDate*** and ***lastDate*** included.

Precondition:
begin*-*end must equal the number of days from ***firstDate*** to ***lastDate*** included.

11.102.2.3 History (const Date & *firstDate*, const Date & *lastDate*, const std::vector< double > & *values*) [inline]

This constructor initializes the history with the given set of values, corresponding to the date range between ***firstDate*** and ***lastDate*** included.

Precondition:
The size of ***values*** must equal the number of days from ***firstDate*** to ***lastDate*** included.

11.102.2.4 History (const std::vector< Date > & *dates*, const std::vector< double > & *values*) [inline]

This constructor initializes the history with the given set of values, corresponding each to the element with the same index in the given set of dates. The whole date range between ***dates***[0] and ***dates***[N-1] will be automatically filled by inserting null values where a date is missing from the given set.

Precondition:

dates must be sorted.
There can be no pairs (***dates***[i],***values***[i]) and (***dates***[j],***values***[j]) such that `dates[i] == dates[j] && values[i] != values[j]`. Pairs with `dates[i] == dates[j] && values[i] == values[j]` are allowed; the duplicated entries will be discarded.
The size of ***values*** must equal the number of days from ***firstDate*** to ***lastDate*** included.

The documentation for this class was generated from the following file:

- history.hpp

11.103 QuantLib::History::const_iterator Class Reference

random access iterator on history entries.

`#include <history.hpp>`

Public Types

- typedef Entry **value_type**
- typedef int **difference_type**
- typedef const Entry * **pointer**
- typedef const Entry & **reference**

Public Methods

Dereferencing

- reference **operator** * () const
- pointer **operator** -> () const

Random access

- value_type **operator[ ]** (difference_type i) const

Increment and decrement

- const_iterator & **operator++** ()
- const_iterator **operator++** (int)
- const_iterator & **operator--** ()
- const_iterator **operator--** (int)
- const_iterator & **operator+=** (difference_type i)
- const_iterator & **operator-=** (difference_type i)
- const_iterator **operator+** (difference_type i)
- const_iterator **operator-** (difference_type i)

Difference

- difference_type **operator-** (const const_iterator &i)

Comparisons

- bool **operator==** (const const_iterator &i)
- bool **operator!=** (const const_iterator &i)
- bool **operator<** (const const_iterator &i)
- bool **operator>** (const const_iterator &i)
- bool **operator<=** (const const_iterator &i)
- bool **operator>=** (const const_iterator &i)

Friends

- class **History**

The documentation for this class was generated from the following file:

- history.hpp

11.104 QuantLib::History::Entry Class Reference

single datum in history.

`#include <history.hpp>`

Public Methods

- const Date & **date** () const
- double **value** () const

Friends

- class **const_iterator**

The documentation for this class was generated from the following file:

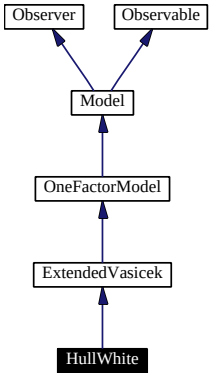
- history.hpp

11.105 QuantLib::InterestRateModelling::HullWhite Class Reference

Analytically tractable single-factor Hull-White model class.

`#include <hullwhite.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::HullWhite:



Public Methods

- **HullWhite** (const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**HullWhite** ()
- virtual Handle< Lattices::Tree > tree (const TimeGrid &grid) const

  Return a recombining tree.

- double **discountBond** (Time T, Time s, Rate r) const
- double **discountBondOption** (Option::Type type, double strike, Time maturity, Time bondMaturity) const

Protected Methods

- virtual void **generateParameters** ()

11.105.1 Detailed Description

This class implements the standard single-factor Hull-White model defined by

$$dr_t = (\theta(t) - \alpha r_t)dt + \sigma dW_t$$

where α and σ are constants. $\varphi(t)$ is analytically defined by

$$\varphi(t) = f(t) + \frac{1}{2}[\frac{\sigma(1-e^{-at})}{a}]^2$$

There is an analytical formula for discount bonds:

$$P(t,T,r_t) =$$

The documentation for this class was generated from the following files:

- hullwhite.hpp
- hullwhite.cpp

11.106 QuantLib::RandomNumbers::ICGaussianRng Class Template Reference

Inverse cumulative Gaussian random number generator.

`#include <inversecumgaussianrng.hpp>`

Public Types

- typedef MonteCarlo::Sample< double > **sample_type**

Public Methods

- **ICGaussianRng** (long seed=0)
- sample_type next () const

  returns next sample from the Gaussian distribution.

11.106.1 Detailed Description

template<class U> class QuantLib::RandomNumbers::ICGaussianRng< U >

It uses a uniform deviate in (0, 1) as the source of cumulative normal distribution values. Then an inverse cumulative normal distribution is used as it is approximately a Gaussian deviate with average 0.0 and standard deviation 1.0.

The uniform deviate is supplied by U.

Class U must implement the following interface:

```
U::U(long seed);
U::sample_type U::next() const;
```

The documentation for this class was generated from the following file:

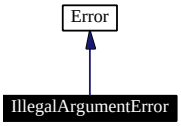
- inversecumgaussianrng.hpp

11.107 QuantLib::IllegalArgumentError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::IllegalArgumentError:



Public Methods

- **IllegalArgumentError** (const std::string &what="")

11.107.1 Detailed Description

Thrown upon passing an argument with an illegal value.

The documentation for this class was generated from the following file:

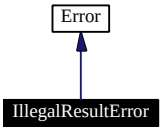
- errors.hpp

11.108 QuantLib::IllegalResultError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::IllegalResultError:



Public Methods

- **IllegalResultError** (const std::string &what="")

11.108.1 Detailed Description

Thrown upon obtaining a result outside the allowed range.

The documentation for this class was generated from the following file:

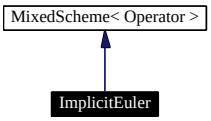
- errors.hpp

11.109 QuantLib::FiniteDifferences::ImplicitEuler Class Template Reference

Backward Euler scheme for finite difference methods.

`#include <impliciteuler.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::ImplicitEuler:



Friends

- class **FiniteDifferenceModel**< **ImplicitEuler**< **Operator** > >

11.109.1 Detailed Description

template<**class Operator**> **class QuantLib::FiniteDifferences::ImplicitEuler**< **Operator** >

See sect. The finite differences framework for details on the method.

In this implementation, the passed operator must be derived from either TimeConstantOperator or TimeDependentOperator. Also, it must implement at least the following interface:

```
typedef ... arrayType;

// copy constructor/assignment
// (these will be provided by the compiler if none is defined)
Operator(const Operator&);
Operator& operator=(const Operator&);

// inspectors
Size size();

// modifiers
void setTime(Time t);

// operator interface
arrayType solveFor(const arrayType&);
static Operator identity(Size size);

// operator algebra
Operator operator*(double, const Operator&);
Operator operator+(const Operator&, const Operator&);
```

The documentation for this class was generated from the following file:

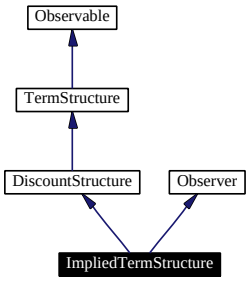
- impliciteuler.hpp

11.110 QuantLib::ImpliedTermStructure Class Reference

Implied term structure at a given date in the future.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::ImpliedTermStructure:



Public Methods

- **ImpliedTermStructure** (const RelinkableHandle< TermStructure > &, const Date &todaysDate)

TermStructure interface

- Currency currency () const
  returns the currency upon which the term structure is defined.
- Date todaysDate () const
  returns today's date.
- int settlementDays () const
  returns the number of settlement days.
- Calendar calendar () const
  returns the calendar for settlement calculation.
- DayCounter dayCounter () const
  returns the day counter.
- Date settlementDate () const
  returns the settlement date.
- Date maxDate () const
  returns the latest date for which the curve can return rates.
- Date minDate () const
  returns the earliest date for which the curve can return rates.
- Time maxTime () const
  returns the latest date for which the curve can return rates.
- Time minTime () const

returns the earliest time for which the curve can return rates.

Observer interface

- void update ()

Protected Methods

- DiscountFactor discountImpl (Time, bool extrapolate=false) const

  returns the discount factor as seen from the evaluation date.

11.110.1 Detailed Description

The given date will be the implied today's date.

Note:
This term structure will remain linked to the original structure, i.e., any changes in the latter will be reflected in this structure as well.

11.110.2 Member Function Documentation

11.110.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

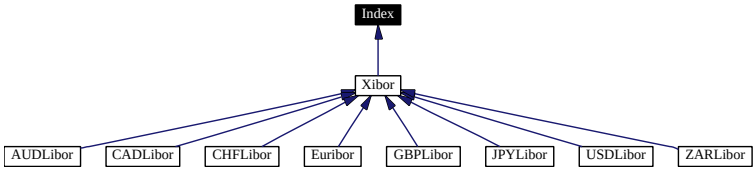
- termstructure.hpp

11.111 QuantLib::Index Class Reference

purely virtual base class for indexes.

`#include <index.hpp>`

Inheritance diagram for QuantLib::Index:



Public Methods

- virtual ~**Index** ()
- virtual std::string name () const=0

  Returns the name of the index.

- virtual Rate fixing (const Date &fixingDate) const=0

  returns the fixing at the given date.

11.111.1 Member Function Documentation

11.111.1.1 virtual std::string name () const [pure virtual]

Warning:
This method is used for output and comparison between indexes. It is **not** meant to be used for writing switch-on-type code.

Implemented in QuantLib::Indexes::Xibor.

11.111.1.2 virtual Rate fixing (const Date & *fixingDate*) const [pure virtual]

Note:
any date passed as arguments must be a value date, i.e., the real calendar date advanced by a number of settlement days.

Implemented in QuantLib::Indexes::Xibor.

The documentation for this class was generated from the following file:

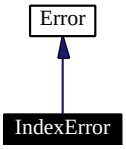
- index.hpp

11.112 QuantLib::IndexError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::IndexError:



Public Methods

- **IndexError** (const std::string &what="")

11.112.1 Detailed Description

Thrown upon accessing an array or container outside its range.

The documentation for this class was generated from the following file:

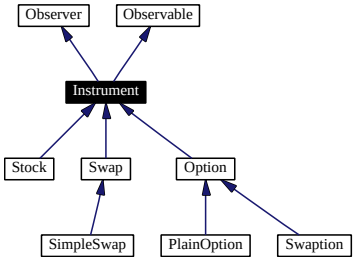
- errors.hpp

11.113 QuantLib::Instrument Class Reference

Abstract instrument class.

`#include <instrument.hpp>`

Inheritance diagram for QuantLib::Instrument:



Calculations

These methods do not modify the structure of the instrument and are therefore declared as `const`. Temporary variables will be declared as mutable.

- void recalculate ()
- void calculate () const
- virtual void performCalculations () const=0

Public Methods

- **Instrument** (const std::string &isinCode="", const std::string &description="")
- virtual ~**Instrument** ()

Inspectors

- std::string isinCode () const
  returns the ISIN code of the instrument, when given.
- std::string description () const
  returns a brief textual description of the instrument.
- double NPV () const
  returns the net present value of the instrument.
- bool isExpired () const
  returns whether the instrument is still tradable.

Observer interface

- void update ()

Protected Attributes

Results

The value of these attributes must be set in the body of the **performCalculations** *method.*

- double **NPV_**
- bool **isExpired_**

11.113.1 Detailed Description

This class is purely abstract and defines the interface of concrete instruments which will be derived from this one.

11.113.2 Member Function Documentation

11.113.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

11.113.2.2 void recalculate () [inline]

This method force the recalculation of the instrument value and other results which would otherwise be cached. It is not declared as const since it needs to call the non-const **notifyObservers** method.

Note:
Explicit invocation of this method is **not** necessary if the instrument registered itself as observer with the structures on which such results depend. It is strongly advised to follow this policy when possible.

11.113.2.3 void calculate () const [inline, protected]

This method performs all needed calculations by calling the **performCalculations** method.

Warning:
Instruments cache the results of the previous calculation. Such results will be returned upon later invocations of **calculate**. When the results depend on parameters such as term structures which could change between invocations, the instrument must register itself as observer of such objects for the calculations to be performed again when they change.

Warning:
This method should **not** be redefined in derived classes.

11.113.2.4 virtual void performCalculations () const [protected, pure virtual]

This method must implement any calculations which must be (re)done in order to calculate the NPV of the instrument.

Implemented in QuantLib::Instruments::PlainOption.

The documentation for this class was generated from the following file:

- instrument.hpp

11.114 QuantLib::IntegerFormatter Class Reference

Formats integers for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (int i, int digits=0)

The documentation for this class was generated from the following files:

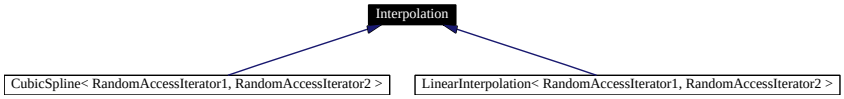
- dataformatters.hpp
- dataformatters.cpp

11.115 QuantLib::Math::Interpolation Class Template Reference

abstract base class for 1-D interpolations.

`#include <interpolation.hpp>`

Inheritance diagram for QuantLib::Math::Interpolation:



Public Methods

- **Interpolation** (const RandomAccessIterator1 &xBegin, const RandomAccessIterator1 &xEnd, const RandomAccessIterator2 &yBegin, bool allowExtrapolation)
- virtual result_type operator() (const argument_type &x) const=0

Public Attributes

- typedef< RandomAccessIterator1 >::value_type **argument_type**
- typedef< RandomAccessIterator2 >::value_type **result_type**

Protected Attributes

- RandomAccessIterator1 **xBegin_**
- RandomAccessIterator1 **xEnd_**
- RandomAccessIterator2 **yBegin_**
- bool **allowExtrapolation_**

11.115.1 Detailed Description

template<class RandomAccessIterator1, class RandomAccessIterator2> class QuantLib::Math::Interpolation< RandomAccessIterator1, RandomAccessIterator2 >

Classes derived from this class will override operator() to provide interpolated values from two sequences of equal length, representing discretized values of a variable and a function of the former, respectively.

11.115.2 Member Function Documentation

11.115.2.1 virtual result_type operator() (const argument_type & *x*) const [pure virtual]

This operator must be overridden to provide an implementation of the actual interpolation.

Precondition:
The sequence of values for x must have been sorted for the result to make sense.

Implemented in QuantLib::Math::CubicSpline.

The documentation for this class was generated from the following file:

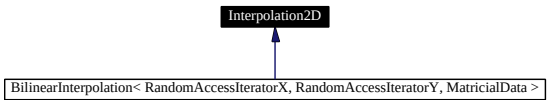
- interpolation.hpp

11.116 QuantLib::Math::Interpolation2D Class Template Reference

abstract base class for 2-D interpolations.

`#include <interpolation2D.hpp>`

Inheritance diagram for QuantLib::Math::Interpolation2D:



Public Types

- typedef double **result_type**

Public Methods

- **Interpolation2D** (const RandomAccessIteratorX &xBegin, const RandomAccessIteratorX &xEnd, const RandomAccessIteratorY &yBegin, const RandomAccessIteratorY &yEnd, const MatricialData &data, bool allowExtrapolation)
- virtual ~**Interpolation2D** ()
- virtual double operator() (const first_argument_type &x, const second_argument_type &y) const=0

Public Attributes

- typedef< RandomAccessIteratorX >::value_type **first_argument_type**
- typedef< RandomAccessIteratorY >::value_type **second_argument_type**

Protected Attributes

- RandomAccessIteratorX **xBegin_**
- RandomAccessIteratorX **xEnd_**
- RandomAccessIteratorY **yBegin_**
- RandomAccessIteratorY **yEnd_**
- const MatricialData & **data_**
- bool **allowExtrapolation_**

11.116.1 Detailed Description

template<class RandomAccessIteratorX, class RandomAccessIteratorY, class MatricialData> class QuantLib::Math::Interpolation2D< RandomAccessIteratorX, RandomAccessIteratorY, MatricialData >

Classes derived from this class will override operator() to provide interpolated values from two sequences of length N and M, representing the discretized values of the x,y variables, and a NxM matrix representing the function tabulated z values.

Todo:
Bicubic interpolation and bicubic spline

11.116.2 Member Function Documentation

11.116.2.1 virtual double operator() (const first_argument_type & *x*, const second_argument_type & *y*) const [pure virtual]

This operator must be overridden to provide an implementation of the actual interpolation.

Precondition:
The sequence of values for x must have been sorted for the result to make sense.

Implemented in QuantLib::Math::BilinearInterpolation.

The documentation for this class was generated from the following file:

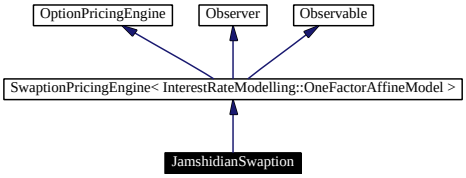
- interpolation2D.hpp

11.117 QuantLib::Pricers::JamshidianSwaption Class Reference

Jamshidian swaption pricer.

`#include <jamshidianswaption.hpp>`

Inheritance diagram for QuantLib::Pricers::JamshidianSwaption:



Public Methods

- **JamshidianSwaption** (const Handle< InterestRateModelling::OneFactorAffineModel > &modl)
- void **calculate** () const

Friends

- class **rStarFinder**

The documentation for this class was generated from the following files:

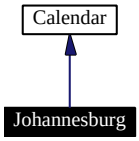
- jamshidianswaption.hpp
- jamshidianswaption.cpp

11.118 QuantLib::Calendars::Johannesburg Class Reference

Johannesburg calendar.

`#include <johannesburg.hpp>`

Inheritance diagram for QuantLib::Calendars::Johannesburg:



Public Methods

- **Johannesburg** ()

11.118.1 Detailed Description

Holidays:

- Sundays
- New Year's Day, January 1st (possibly moved to Monday)
- Good Friday
- Family Day, Easter Monday
- Human Rights Day, March 21st (possibly moved to Monday)
- Freedom Day, April 27th (possibly moved to Monday)
- Workers Day, May 1st (possibly moved to Monday)
- Youth Day, June 16th (possibly moved to Monday)
- National Women's Day, August 9th (possibly moved to Monday)
- Heritage Day, September 24th (possibly moved to Monday)
- Day of Reconciliation, December 16th (possibly moved to Monday)
- Christmas December 25th
- Day of Goodwill December 26th (possibly moved to Monday)

The documentation for this class was generated from the following file:

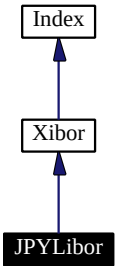
- johannesburg.hpp

11.119 QuantLib::Indexes::JPYLibor Class Reference

JPY Libor index (Also known as TIBOR, check settlement days).

`#include <jpylibor.hpp>`

Inheritance diagram for QuantLib::Indexes::JPYLibor:



Public Methods

- **JPYLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

- jpylibor.hpp

11.120 QuantLib::RandomNumbers::KnuthUniformRng Class Reference

Uniform random number generator.

`#include <knuthuniformrng.hpp>`

Public Types

- typedef MonteCarlo::Sample< double > **sample_type**

Public Methods

- KnuthUniformRng (long seed=0)
- sample_type next () const

11.120.1 Detailed Description

Random number generator by Knuth. For more details see Knuth, Seminumerical Algorithms, 3rd edition, Section 3.6.

Note:

This is **not** Knuth's original implementation which is available at `http://www-cs-faculty.stanford.edu/~knuth/programs.html`, but rather a slightly modified version wrapped in a C++ class. Such modifications did not affect the code but only the data structures used, which were converted in their C++/STL equivalents.

11.120.2 Constructor & Destructor Documentation

11.120.2.1 KnuthUniformRng (long *seed* = 0) `[explicit]`

if the given seed is 0, a random seed will be chosen based on clock()

11.120.3 Member Function Documentation

11.120.3.1 KnuthUniformRng::sample_type next () const `[inline]`

returns a sample with weight 1.0 containing a random number uniformly chosen from (0.0,1.0)

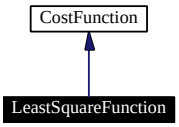
The documentation for this class was generated from the following files:

- knuthuniformrng.hpp
- knuthuniformrng.cpp

11.121 QuantLib::Optimization::LeastSquareFunction Class Reference

`#include <leastsquare.hpp>`

Inheritance diagram for QuantLib::Optimization::LeastSquareFunction:



Public Methods

- LeastSquareFunction (LeastSquareProblem &lsp)
  Default constructor.
- virtual ~LeastSquareFunction ()
  Destructor.
- virtual double value (const Array &x)
  compute value of the least square function.
- virtual void gradient (Array &grad_f, const Array &x)
  compute vector of derivatives of the least square function.
- virtual double valueAndGradient (Array &grad_f, const Array &x)
  compute value and vector of derivatives of the least square function.

Protected Attributes

- LeastSquareProblem & lsp_
  least square problem.

11.121.1 Detailed Description

Design a least square function as a cost function using the interface provided by LeastSquareProblem class. Array vector class requires function DotProduct() that computes dot product and - operator M matrix class requires function transpose() that computes transpose and * operator with vector class

The documentation for this class was generated from the following file:

- leastsquare.hpp

11.122 QuantLib::RandomNumbers::LecuyerUniformRng Class Reference

Uniform random number generator.

`#include <lecuyeruniformrng.hpp>`

Public Types

- typedef MonteCarlo::Sample< double > **sample_type**

Public Methods

- LecuyerUniformRng (long seed=0)
- sample_type next () const

11.122.1 Detailed Description

Random number generator of L'Ecuyer with added Bays-Durham shuffle. For more details see Section 7.1 of Numerical Recipes in C, 2nd Edition, Cambridge University Press (available at `http://www.nr.com/`)

11.122.2 Constructor & Destructor Documentation

11.122.2.1 LecuyerUniformRng (long *seed* = 0) `[inline, explicit]`

if the given seed is 0, a random seed will be chosen based on clock()

11.122.3 Member Function Documentation

11.122.3.1 LecuyerUniformRng::sample_type next () const `[inline]`

returns a sample with weight 1.0 containing a random number uniformly chosen from (0.0,1.0)

The documentation for this class was generated from the following files:

- lecuyeruniformrng.hpp
- lecuyeruniformrng.cpp

11.123 QuantLib::Math::LexicographicalView Class Template Reference

Lexicographical 2-D view of a contiguous set of data.

`#include <lexicographicalview.hpp>`

Public Types

- typedef RandomAccessIterator x_iterator
  iterates over v_{ij} with j fixed.
- typedef Utilities::stepping_iterator< RandomAccessIterator > y_iterator
  iterates over v_{ij} with i fixed.

Public Methods

- LexicographicalView (const RandomAccessIterator &begin, const RandomAccessIterator &end, int xSize)
  attaches the view with the given dimension to a sequence.
- typedef QL_REVERSE_ITERATOR (RandomAccessIterator, typename 1< RandomAccessIterator >::value_type) reverse_x_iterator
  iterates backwards over v_{ij} with j fixed.
- typedef QL_REVERSE_ITERATOR (y_iterator, typename 1< RandomAccessIterator >::value_type) reverse_y_iterator
  iterates backwards over v_{ij} with i fixed.

Element access

- y_iterator **operator[ ]** (int i)

Iterator access

- x_iterator **xbegin** (int j)
- x_iterator **xend** (int j)
- reverse_x_iterator **rxbegin** (int j)
- reverse_x_iterator **rxend** (int j)
- y_iterator **ybegin** (int i)
- y_iterator **yend** (int i)
- reverse_y_iterator **rybegin** (int i)
- reverse_y_iterator **ryend** (int i)

Inspectors

- int xSize () const
  dimension of the array along x.
- int ySize () const
  dimension of the array along y.

11.123.1 Detailed Description

template<class RandomAccessIterator> class QuantLib::Math::LexicographicalView< RandomAccessIterator >

This view can be used to easily store a discretized 2-D function in an array to be used in a finite differences calculation.

The documentation for this class was generated from the following file:

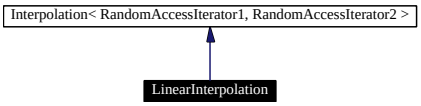
- lexicographicalview.hpp

11.124 QuantLib::Math::LinearInterpolation Class Template Reference

linear interpolation between discrete points.

`#include <linearinterpolation.hpp>`

Inheritance diagram for QuantLib::Math::LinearInterpolation:



Public Methods

- **LinearInterpolation** (const RandomAccessIterator1 &xBegin, const RandomAccessIterator1 &xEnd, const RandomAccessIterator2 &yBegin, bool allowExtrapolation)
- result_type operator() (const argument_type &x) const

Public Attributes

- typedef< RandomAccessIterator1 >::value_type **argument_type**
- typedef< RandomAccessIterator2 >::value_type **result_type**

template<class RandomAccessIterator1, class RandomAccessIterator2> class QuantLib::Math::LinearInterpolation< RandomAccessIterator1, RandomAccessIterator2 >

11.124.1 Member Function Documentation

11.124.1.1 result_type operator() (const argument_type & *x*) const `[virtual]`

This operator must be overridden to provide an implementation of the actual interpolation.

Precondition:
The sequence of values for x must have been sorted for the result to make sense.

Implements QuantLib::Math::Interpolation.

The documentation for this class was generated from the following file:

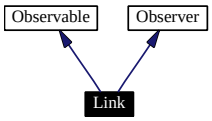
- linearinterpolation.hpp

11.125 QuantLib::Link Class Template Reference

Relinkable access to a Handle.

`#include <relinkablehandle.hpp>`

Inheritance diagram for QuantLib::Link:



Public Methods

- Link (const Handle< Type > &h=Handle< Type >(), bool registerAsObserver=true)
- void linkTo (const Handle< Type > &h, bool registerAsObserver=true)
- bool isNull () const

  Checks if the contained handle points to anything.

- const Handle< Type > & currentLink () const

  Returns the contained handle.

- void update ()

  Observer interface.

11.125.1 Detailed Description

template<class Type> class QuantLib::Link< Type >

Precondition:
Class "Type" must inherit from Observable

11.125.2 Constructor & Destructor Documentation

11.125.2.1 Link (const Handle< Type > & *h* = Handle< Type >(), bool *registerAsObserver* = true) [inline]

Warning:
see the documentation of the `linkTo` method for issues relatives to `registerAsObserver`.

11.125.3 Member Function Documentation

11.125.3.1 void linkTo (const Handle< Type > & *h*, bool *registerAsObserver* = true) [inline]

Warning:
registerAsObserver is left as a backdoor in case the programmer cannot guarantee that the object pointed to will remain alive for the whole lifetime of the handle—namely, it should be set to `false` when the passed handle was created with `owns = false` (the latter should only happen in a controlled environment, so that the programmer is aware of it). Failure to do so can very likely result in

a program crash. If the programmer does want the relinkable handle to register as observer of such a handle, it is his responsibility to ensure that the relinkable handle gets destroyed before the pointed object does.

The documentation for this class was generated from the following file:

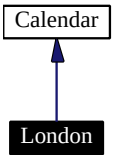
- relinkablehandle.hpp

11.126 QuantLib::Calendars::London Class Reference

London calendar.

`#include <london.hpp>`

Inheritance diagram for QuantLib::Calendars::London:



Public Methods

- **London** ()

11.126.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st (possibly moved to Monday)
- Good Friday
- Easter Monday
- Bank Holiday, first Monday of May
- Bank Holiday, last Monday of May
- Bank Holiday, last Monday of August
- Christmas, December 25th (possibly moved to Monday or Tuesday)
- Boxing Day, December 26th (possibly moved to Monday or Tuesday)

The documentation for this class was generated from the following file:

- london.hpp

11.127 QuantLib::Utilities::lowest_category_iterator Struct Template Reference

most generic of two given iterator categories.

`#include <iteratorcategories.hpp>`

11.127.1 Detailed Description

template<class Category1, class Category2> struct QuantLib::Utilities::lowest_category_iterator< Category1, Category2 >

Specializations of this struct define a typedef iterator_category which corresponds to the most generic of the two input categories, e.g., lowest_category_iterator<std::random_access_iterator_tag, std::forward_iterator_tag>iterator_category corresponds to std::forward_iterator_tag.

The documentation for this struct was generated from the following file:

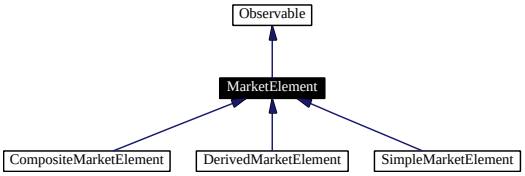
- iteratorcategories.hpp

11.128 QuantLib::MarketElement Class Reference

purely virtual base class for market observables.

`#include <marketelement.hpp>`

Inheritance diagram for QuantLib::MarketElement:



Public Methods

- virtual ~**MarketElement** ()
- virtual double value () const=0

  returns the current value.

The documentation for this class was generated from the following file:

- marketelement.hpp

11.129 QuantLib::Math::Matrix Class Reference

matrix used in linear algebra.

`#include <matrix.hpp>`

Public Types

- typedef double * **iterator**
- typedef const double * **const_iterator**
- typedef double * **row_iterator**
- typedef const double * **const_row_iterator**
- typedef Utilities::stepping_iterator< double * > **column_iterator**
- typedef Utilities::stepping_iterator< const double * > **const_column_iterator**

Public Methods

- typedef **QL_REVERSE_ITERATOR** (iterator, double) reverse_iterator
- typedef **QL_REVERSE_ITERATOR** (const_iterator, double) const _reverse_iterator
- typedef **QL_REVERSE_ITERATOR** (row_iterator, double) reverse_row_iterator
- typedef **QL_REVERSE_ITERATOR** (const_row_iterator, double) const _reverse_row_iterator
- typedef **QL_REVERSE_ITERATOR** (column_iterator, double) reverse_column_iterator
- typedef **QL_REVERSE_ITERATOR** (const_column_iterator, double) const _reverse_column_-iterator

Constructors, destructor, and assignment

- Matrix ()

  creates a null matrix.

- Matrix (Size rows, Size columns)

  creates a matrix with the given dimensions.

- Matrix (Size rows, Size columns, double value)

  creates the matrix and fills it with `value`.

- **Matrix** (const Matrix &)
- ~**Matrix** ()
- Matrix & **operator=** (const Matrix &)

Algebraic operators

- Matrix & operator+= (const Matrix &)
- Matrix & **operator-=** (const Matrix &)
- Matrix & **operator** *= (double)
- Matrix & **operator/=** (double)

Iterator access

- const_iterator **begin** () const
- iterator **begin** ()
- const_iterator **end** () const

- iterator **end** ()
- const_reverse_iterator **rbegin** () const
- reverse_iterator **rbegin** ()
- const_reverse_iterator **rend** () const
- reverse_iterator **rend** ()
- const_row_iterator **row_begin** (Size i) const
- row_iterator **row_begin** (Size i)
- const_row_iterator **row_end** (Size i) const
- row_iterator **row_end** (Size i)
- const_reverse_row_iterator **row_rbegin** (Size i) const
- reverse_row_iterator **row_rbegin** (Size i)
- const_reverse_row_iterator **row_rend** (Size i) const
- reverse_row_iterator **row_rend** (Size i)
- const_column_iterator **column_begin** (Size i) const
- column_iterator **column_begin** (Size i)
- const_column_iterator **column_end** (Size i) const
- column_iterator **column_end** (Size i)
- const_reverse_column_iterator **column_rbegin** (Size i) const
- reverse_column_iterator **column_rbegin** (Size i)
- const_reverse_column_iterator **column_rend** (Size i) const
- reverse_column_iterator **column_rend** (Size i)

Element access

- const_row_iterator **operator[ ]** (Size) const
- row_iterator **operator[ ]** (Size)
- Array **diagonal** (void) const

Inspectors

- Size **rows** () const
- Size **columns** () const

Related Functions

(Note that these are not member functions.)

- Matrix **operator+** (const Matrix &, const Matrix &)
- Matrix **operator-** (const Matrix &, const Matrix &)
- Matrix **operator** * (const Matrix &, double)
- Matrix **operator** * (double, const Matrix &)
- Matrix **operator/** (const Matrix &, double)
- Array **operator** * (const Array &, const Matrix &)
- Array **operator** * (const Matrix &, const Array &)
- Matrix **operator** * (const Matrix &, const Matrix &)
- Matrix **transpose** (const Matrix &)
- Matrix **outerProduct** (const Array &v1, const Array &v2)
- Matrix matrixSqrt (const Matrix &realSymmetricMatrix)

  returns the square root of a real symmetric matrix.

11.129.1 Detailed Description

This class implements the concept of vector as used in linear algebra. As such, it is **not** meant to be used as a container.

11.129.2 Member Function Documentation

11.129.2.1 Matrix & operator+= (const Matrix &) [inline]

Precondition:
all matrices involved in an algebraic expression must have the same size.

The documentation for this class was generated from the following file:

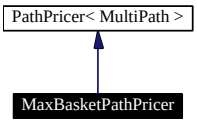
- matrix.hpp

11.130 QuantLib::MonteCarlo::MaxBasketPathPricer Class Reference

multipath pricer for European-type basket option.

`#include <maxbasketpathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::MaxBasketPathPricer:



Public Methods

- **MaxBasketPathPricer** (const Array &underlying, DiscountFactor discount, bool useAntithetic-Variance)
- double **operator()** (const MultiPath &multiPath) const

11.130.1 Detailed Description

The value of the option at expiration is given by the value of the underlying which has best performed.

The documentation for this class was generated from the following files:

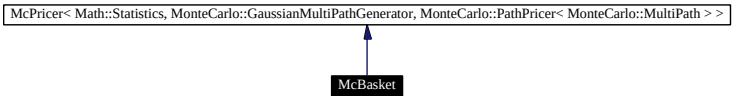
- maxbasketpathpricer.hpp
- maxbasketpathpricer.cpp

11.131 QuantLib::Pricers::McBasket Class Reference

simple example of multi-factor Monte Carlo pricer.

`#include <mcbasket.hpp>`

Inheritance diagram for QuantLib::Pricers::McBasket:



Public Methods

- **McBasket** (Option::Type type, const Array &underlying, double strike, const Array &dividendYield, const Math::Matrix &covariance, Rate riskFreeRate, double residualTime, bool antitheticVariance, long seed=0)

The documentation for this class was generated from the following files:

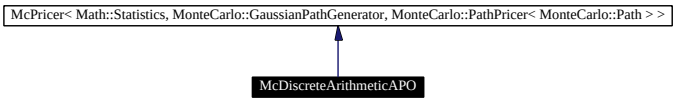
- mcbasket.hpp
- mcbasket.cpp

11.132 QuantLib::Pricers::McDiscreteArithmeticAPO Class Reference

example of Monte Carlo pricer using a control variate.

`#include <mcdiscretearithmeticapo.hpp>`

Inheritance diagram for QuantLib::Pricers::McDiscreteArithmeticAPO:



Public Methods

- **McDiscreteArithmeticAPO** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, const std::vector< Time > &times, double volatility, bool antitheticVariance, bool controlVariate, long seed=0)

11.132.1 Detailed Description

Todo:

Continous Averaging version

The documentation for this class was generated from the following files:

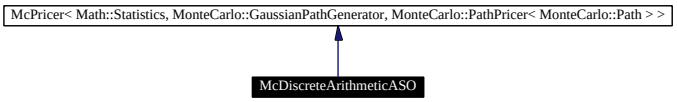
- mcdiscretearithmeticapo.hpp
- mcdiscretearithmeticapo.cpp

11.133 QuantLib::Pricers::McDiscreteArithmeticASO Class Reference

example of Monte Carlo pricer using a control variate.

`#include <mcdiscretearithmeticaso.hpp>`

Inheritance diagram for QuantLib::Pricers::McDiscreteArithmeticASO:



Public Methods

- **McDiscreteArithmeticASO** (Option::Type type, double underlying, Spread dividendYield, Rate riskFreeRate, const std::vector< Time > &times, double volatility, bool antitheticVariance, bool controlVariate, long seed=0)

11.133.1 Detailed Description

Todo:

Continous Averaging version

The documentation for this class was generated from the following files:

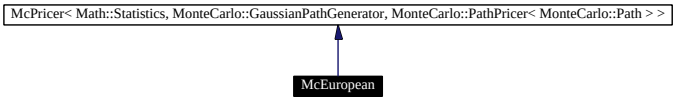
- mcdiscretearithmeticaso.hpp
- mcdiscretearithmeticaso.cpp

11.134 QuantLib::Pricers::McEuropean Class Reference

simple example of Monte Carlo pricer.

`#include <mceuropean.hpp>`

Inheritance diagram for QuantLib::Pricers::McEuropean:



Public Methods

- **McEuropean** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, double residualTime, double volatility, bool antitheticVariance, long seed=0)

11.134.1 Detailed Description

Examples:
EuropeanOption.cpp.

The documentation for this class was generated from the following files:

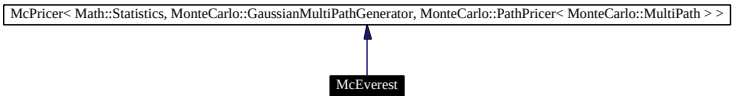
- mceuropean.hpp
- mceuropean.cpp

11.135 QuantLib::Pricers::McEverest Class Reference

Everest-type option pricer.

`#include <mceverest.hpp>`

Inheritance diagram for QuantLib::Pricers::McEverest:



Public Methods

- **McEverest** (const Array &dividendYield, const Math::Matrix &covariance, Rate riskFreeRate, Time residualTime, bool antitheticVariance, long seed=0)

11.135.1 Detailed Description

The payoff of an Everest option is simply given by the final price / initial price ratio of the worst performer

The documentation for this class was generated from the following file:

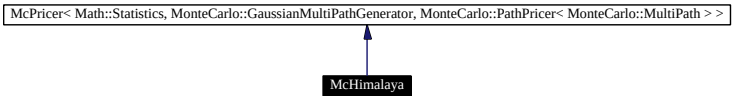
- mceverest.hpp

11.136 QuantLib::Pricers::McHimalaya Class Reference

Himalayan-type option pricer.

`#include <mchimalaya.hpp>`

Inheritance diagram for QuantLib::Pricers::McHimalaya:



Public Methods

- **McHimalaya** (const Array &underlying, const Array &dividendYield, const Math::Matrix &covariance, Rate riskFreeRate, double strike, const std::vector< Time > &times, bool antitheticVariance, long seed=0)

11.136.1 Detailed Description

The payoff of a Himalaya option is computed in the following way: Given a basket of N assets, and N time periods, at end of each period the option who performed the best is added to the average and then discarded from the basket. At the end of the N periods the option pays the max between the strike and the average of the best performers.

The documentation for this class was generated from the following files:

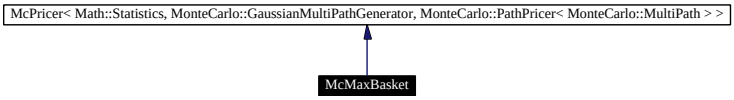
- mchimalaya.hpp
- mchimalaya.cpp

11.137 QuantLib::Pricers::McMaxBasket Class Reference

simple example of multi-factor Monte Carlo pricer.

`#include <mcmaxbasket.hpp>`

Inheritance diagram for QuantLib::Pricers::McMaxBasket:



Public Methods

- **McMaxBasket** (const Array &underlying, const Array &dividendYield, const Math::Matrix &covariance, Rate riskFreeRate, double residualTime, bool antitheticVariance, long seed=0)

The documentation for this class was generated from the following files:

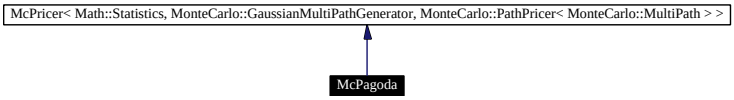
- mcmaxbasket.hpp
- mcmaxbasket.cpp

11.138 QuantLib::Pricers::McPagoda Class Reference

roofed Asian option.

`#include <mcpagoda.hpp>`

Inheritance diagram for QuantLib::Pricers::McPagoda:



Public Methods

- **McPagoda** (const Array &portfolio, double fraction, double roof, const Array &dividendYield, const Math::Matrix &covariance, Rate riskFreeRate, const std::vector< Time > &times, bool antithetic, long seed=0)

11.138.1 Detailed Description

Given a certain portfolio of assets at the end of the period it is returned the minimum of a given roof and a certain fraction of the positive portfolio performance. If the performance of the portfolio is below then the payoff is null.

The documentation for this class was generated from the following file:

- mcpagoda.hpp

11.139 QuantLib::Pricers::McPricer Class Template Reference

base class for Monte Carlo pricers.

`#include <mcpricer.hpp>`

Public Methods

- virtual ~**McPricer** ()
- double value (double tolerance, Size maxSample=QL_MAX_INT) const

  add samples until the required tolerance is reached.

- double valueWithSamples (Size samples) const

  simulate a fixed number of samples.

- double errorEstimate () const

  error Estimated of the samples simulated so far.

- const S & sampleAccumulator (void) const

  access to the sample accumulator for more statistics.

Protected Methods

- **McPricer** ()

Protected Attributes

- Handle< MonteCarlo::MonteCarloModel< S, PG, PP > > **mcModel_**

Static Protected Attributes

- const Size **minSample_** = 100

11.139.1 Detailed Description

template<class S, class PG, class PP> class QuantLib::Pricers::McPricer< S, PG, PP >

Eventually this class might be linked to the general tree of pricers, in order to have tools like impliedVolatility available. Also, it could, eventually, offer greeks methods. Deriving a class from McPricer gives an easy way to write a Monte Carlo Pricer. See McEuropean as example of one factor pricer, Basket as example of multi factor pricer.

The documentation for this class was generated from the following file:

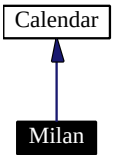
- mcpricer.hpp

11.140 QuantLib::Calendars::Milan Class Reference

Milan calendar.

`#include <milan.hpp>`

Inheritance diagram for QuantLib::Calendars::Milan:



Public Methods

- **Milan** ()

11.140.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Epiphany, January 6th
- Easter Monday
- Liberation Day, April 25th
- Labour Day, May 1st
- Republic Day, June 2nd (since 2000)
- Assumption, August 15th
- All Saint's Day, November 1st
- Immaculate Conception, December 8th
- Christmas, December 25th
- St. Stephen, December 26th

The documentation for this class was generated from the following file:

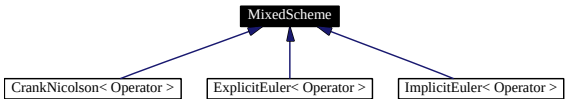
- milan.hpp

11.141 QuantLib::FiniteDifferences::MixedScheme Class Template Reference

Mixed (explicit/implicit) scheme for finite difference methods.

`#include <mixedscheme.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::MixedScheme:



Protected Types

- typedef Operator::arrayType **arrayType**
- typedef Operator **operatorType**

Protected Methods

- **MixedScheme** (const Operator &L, double theta)
- void **step** (arrayType &a, Time t)
- void **setStep** (Time dt)

Protected Attributes

- Operator **L_**
- Operator **I_**
- Operator **explicitPart_**
- Operator **implicitPart_**
- Time **dt_**
- double **theta_**

Friends

- class **FiniteDifferenceModel**< **MixedScheme**< **Operator** > >

11.141.1 Detailed Description

template<**class Operator**> **class QuantLib::FiniteDifferences::MixedScheme**< **Operator** >

See sect. The finite differences framework for details on the method.

In this implementation, the passed operator must be derived from either TimeConstantOperator or TimeDependentOperator. Also, it must implement at least the following interface:

```
typedef ... arrayType;

// copy constructor/assignment
```

```
// (these will be provided by the compiler if none is defined)
Operator(const Operator&);
Operator& operator=(const Operator&);

// inspectors
size_t size();

// modifiers
void setTime(Time t);

// operator interface
arrayType applyTo(const arrayType&);
arrayType solveFor(const arrayType&);
static Operator identity(size_t size);

// operator algebra
Operator operator*(double, const Operator&);
Operator operator+(const Operator&, const Operator&);
Operator operator+(const Operator&, const Operator&);
```

Warning:
The differential operator must be linear for this evolver to work.

Todo:
add Douglas Scheme

The documentation for this class was generated from the following file:

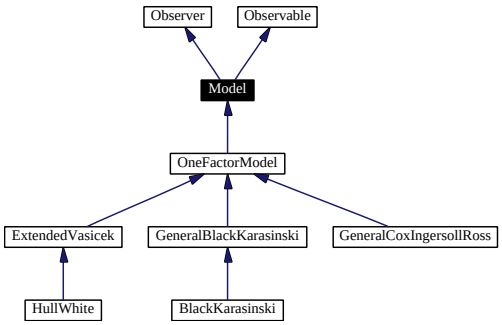
- mixedscheme.hpp

11.142 QuantLib::InterestRateModelling::Model Class Reference

Abstract short-rate model class.

`#include <model.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::Model:



Public Methods

- **Model** (Size nParameters, const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**Model** ()
- void update ()
- void **calibrate** (CalibrationSet &instruments, const Handle< Optimization::OptimizationMethod > &method)
- const RelinkableHandle< TermStructure > & termStructure () const

  Returns the present term structure implied by the model.

Protected Methods

- virtual void **generateParameters** ()

Protected Attributes

- Handle< Optimization::Constraint > **constraint_**
- std::vector< Parameter > **parameters_**

Friends

- class **CalibrationFunction**

11.142.1 Member Function Documentation

11.142.1.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

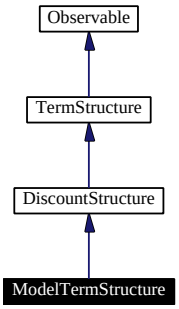
- model.hpp

11.143 QuantLib::InterestRateModelling::ModelTermStructure Class Reference

Term structure implied by a model.

`#include <onefactormodel.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::ModelTermStructure:



Public Methods

- **ModelTermStructure** (const OneFactorAffineModel *model, Time t0, Rate r0)
- virtual DiscountFactor **discountImpl** (Time t, bool extrapolate)

The documentation for this class was generated from the following file:

- onefactormodel.hpp

11.144 QuantLib::MonteCarlo::MonteCarloModel Class Template Reference

General purpose Monte Carlo model for path samples.

`#include <montecarlomodel.hpp>`

Public Types

- typedef PG::sample_type **sample_type**
- typedef PP::result_type **result_type**

Public Methods

- **MonteCarloModel** (const Handle< PG > &pathGenerator, const Handle< PP > &pathPricer, const S &sampleAccumulator, const Handle< PP > &cvPathPricer=Handle< PP >(), result_type cvOptionValue=result_type())
- void **addSamples** (Size samples)
- const S & **sampleAccumulator** (void) const

11.144.1 Detailed Description

template<class S, class PG, class PP> class QuantLib::MonteCarlo::MonteCarloModel< S, PG, PP >

Any Monte Carlo which uses path samples has three main components, namely,

- S, a sample accumulator,
- PG, a path generator,
- PP, a path pricer. MonteCarloModel<S, PG, PP> puts together these three elements. The constructor accepts two safe references, i.e. two smart pointers, one to a path generator and the other to a path pricer. In case of control variate technique the user should provide the additional control option, namely the option path pricer and the option value.

The minimal interfaces for the classes S, PG, and PP are:

```
class S{
    void add(VALUE_TYPE sample, double weight) const;
};

class PG{
    Sample<PATH_TYPE> next() const;
};

class PP :: unary_function<PATH_TYPE, VALUE_TYPE> {
    VALUE_TYPE operator()(PATH_TYPE &) const;
};
```

The documentation for this class was generated from the following file:

- montecarlomodel.hpp

11.145 QuantLib::MonteCarlo::MultiPath Class Reference

single random walk.

`#include <multipath.hpp>`

Public Methods

- **MultiPath** (Size nAsset, Size pathSize)
- **MultiPath** (const std::vector< Path > &multiPath)

inspectors

- Size **assetNumber** () const
- Size **pathSize** () const

read/write access to components

- const Path & **operator[ ]** (Size j) const
- Path & **operator[ ]** (Size j)

11.145.1 Detailed Description

MultiPath contains the list of variations for each asset,

$$\log \frac{Y_{i+1}^j}{Y_i^j} \text{for} i = 0, \ldots, n-1 \qquad \text{and} \qquad j = 0, \ldots, m-1$$

where Y_i^j is the value of the underlying j at discretized time t_i. The first index refers to the underlying, the second to the time position MultiPath[j,i]

Todo:
make it time-aware

The documentation for this class was generated from the following file:

- multipath.hpp

11.146 QuantLib::MonteCarlo::MultiPathGenerator Class Template Reference

Generates a multipath from a random number generator.

`#include <multipathgenerator.hpp>`

Public Types

- typedef Sample< MultiPath > **sample_type**

Public Methods

- **MultiPathGenerator** (const Array &drifts, const Math::Matrix &covariance, Time length, Size timeSteps, long seed)
- **MultiPathGenerator** (const Array &drifts, const Math::Matrix &covariance, const std::vector< Time > &times, long seed=0)
- const sample_type & **next** () const

11.146.1 Detailed Description

template<class RAG> class QuantLib::MonteCarlo::MultiPathGenerator< RAG >

MultiPathGenerator<RAG> is a class that returns a random multi path. RAG is a sample generator which returns a random array. It must have the minimal interface:

```
RAG{
    RAG();
    RAG(Matrix& covariance,
        long seed);
    Sample<Array> next();
};
```

The documentation for this class was generated from the following file:

- multipathgenerator.hpp

11.147 QuantLib::Math::MultivariateAccumulator Class Reference

A sample accumulator for multivariate analysis.

`#include <multivariateaccumulator.hpp>`

Public Methods

- **MultivariateAccumulator** ()
- **MultivariateAccumulator** (Size size)

Inspectors

- Size size () const
  size of each sample.
- Size samples () const
  number of samples collected.
- double weightSum () const
  sum of data weights.
- Array mean () const
  returns the mean as an Array.
- std::vector< double > meanVector () const
  returns the mean as a std::vector<double>.
- Matrix covariance () const
  returns the covariance Matrix.
- Matrix correlation () const
  returns the correlation Matrix.

Modifiers

- void add (const Array &arr, double weight=1.0)
  adds an Array to the collection, possibly with a weight.
- void add (const std::vector< double > &vec, double weight=1.0)
  adds a vector<double> to the collection, possibly with a weight.
- template<class DataIterator> void addSequence (DataIterator begin, DataIterator end)
  adds a sequence of data to the collection.
- template<class DataIterator, class WeightIterator> void addSequence (DataIterator begin, DataIterator end, WeightIterator wbegin)
  adds a sequence of data to the collection, each with its weight.
- void reset ()
  resets the data to a null set.

11.147.1 Detailed Description

MultivariateAccumulator can accumulate vector-type samples and return the average vector, both in Array form and std::vector<double> form, and the covariance matrix

11.147.2 Member Function Documentation

11.147.2.1 Matrix covariance () const

Precondition:
weights must be positive or null

The documentation for this class was generated from the following files:

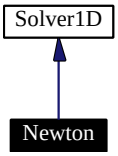
- multivariateaccumulator.hpp
- multivariateaccumulator.cpp

11.148 QuantLib::Solvers1D::Newton Class Reference

Newton 1-D solver.

`#include <newton.hpp>`

Inheritance diagram for QuantLib::Solvers1D::Newton:



The documentation for this class was generated from the following files:

- newton.hpp
- newton.cpp

11.149 QuantLib::Solvers1D::NewtonSafe Class Reference

safe Newton 1-D solver.

`#include <newtonsafe.hpp>`

Inheritance diagram for QuantLib::Solvers1D::NewtonSafe:

The documentation for this class was generated from the following files:

- newtonsafe.hpp
- newtonsafe.cpp

11.150 QuantLib::Calendars::NewYork Class Reference

New York calendar.

`#include <newyork.hpp>`

Inheritance diagram for QuantLib::Calendars::NewYork:

Public Methods

- **NewYork** ()

11.150.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st (possibly moved to Monday if actually on Sunday, or to Friday if on Saturday)
- Martin Luther King's birthday, third Monday in January
- Washington's birthday, third Monday in February
- Memorial Day, last Monday in May
- Independence Day, July 4th (moved to Monday if Sunday or Friday if Saturday)
- Labor Day, first Monday in September
- Columbus Day, second Monday in October
- Veteran's Day, November 11th (moved to Monday if Sunday or Friday if Saturday)
- Thanksgiving Day, fourth Thursday in November
- Christmas, December 25th (moved to Monday if Sunday or Friday if Saturday)

The documentation for this class was generated from the following file:

- newyork.hpp

11.151 QuantLib::Optimization::NonLinearLeastSquare Class Reference

`#include <leastsquare.hpp>`

Public Methods

- NonLinearLeastSquare (Constraint &c, double accuracy=1e-4, int maxiter=100)
  Default constructor.
- NonLinearLeastSquare (Constraint &c, double accuracy, int maxiter, Handle< OptimizationMethod > om)
  Default constructor.
- ~NonLinearLeastSquare ()
  Destructor.
- Array & perform (LeastSquareProblem &lsProblem)
  Solve least square problem using numerix solver.
- void **setInitialValue** (const Array &initialValue)
- Array & results ()
  return the results.
- double residualNorm ()
  return the least square residual norm.
- double lastValue ()
  return last function value.
- int exitFlag ()
  return exit flag.
- int iterationsNumber ()
  return the performed number of iterations.

11.151.1 Detailed Description

Default least square method using a given optimization algorithm (default is conjugate gradient).

min { r(x) : x in R^n }

where r(x) = ||f(x)||^2 the euclidian norm of f(x) for some vector-valued function f from R^n to R^m f = (f1, ..., fm) with fi(x) = bi - phi(x,ti) where bi is the vector of target data and phi is a scalar function.

Assuming the differentiability of f, the gradient of r is define by grad r(x) = f'(x)^t.f(x)

Array vector class has the requirement of the previous class Handle class is need to manage pointer to optimization method

The documentation for this class was generated from the following file:

- leastsquare.hpp

11.152 QuantLib::Null Class Template Reference

template class providing a null value for a given type.

`#include <null.hpp>`

Public Methods

- **Null** ()
- **operator Type** () const

template<class Type> class QuantLib::Null< Type >

The documentation for this class was generated from the following file:

- null.hpp

11.153 QuantLib::ObjectiveFunction Class Reference

Objective function for 1-D solvers.

`#include <solver1d.hpp>`

Public Methods

- virtual ~**ObjectiveFunction** ()
- virtual double operator() (double x) const=0

  returns $f(x)$.

- virtual double derivative (double x) const

  returns $f'(x)$.

11.153.1 Detailed Description

This is the function whose zeroes must be found.

The documentation for this class was generated from the following file:

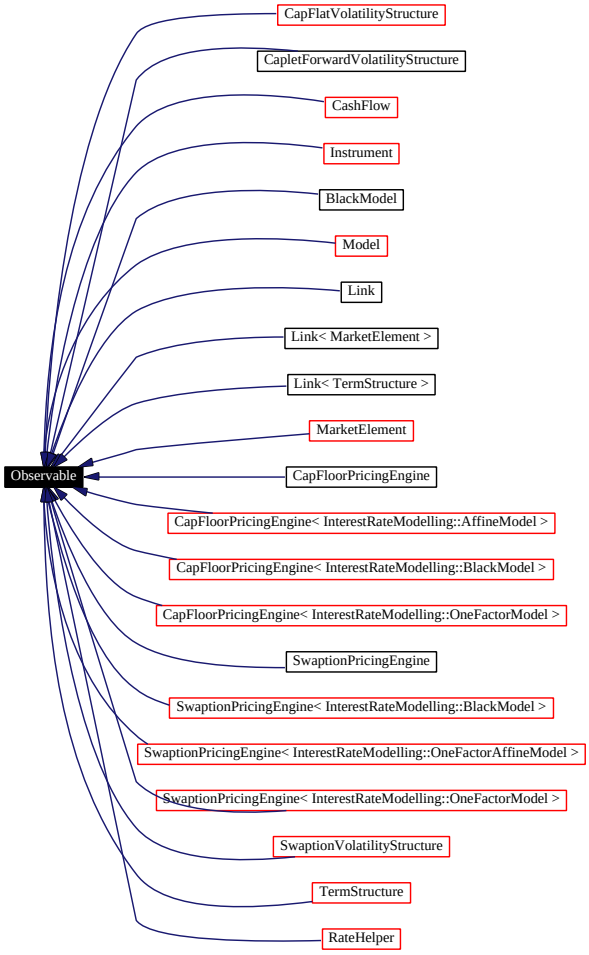
- solver1d.hpp

11.154 QuantLib::Patterns::Observable Class Reference

Object that notifies its changes to a set of observables.

`#include <observable.hpp>`

Inheritance diagram for QuantLib::Patterns::Observable:



Public Methods

- virtual ~**Observable** ()
- void notifyObservers ()

Friends

- class **Observer**

11.154.1 Member Function Documentation

11.154.1.1 void notifyObservers () [inline]

This method should be called at the end of non-const methods or when the programmer desires to notify any changes.

The documentation for this class was generated from the following file:

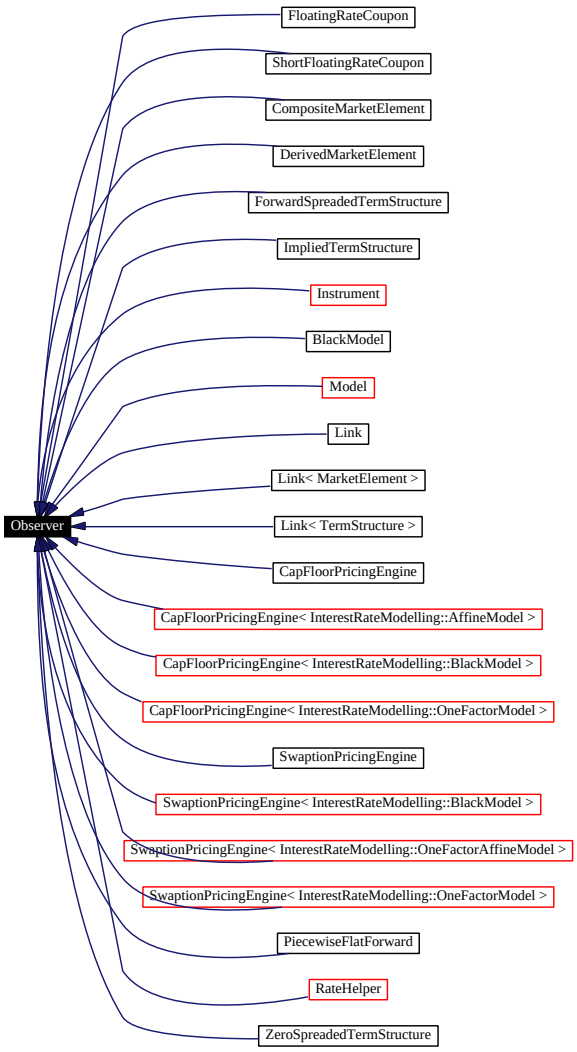
- observable.hpp

11.155 QuantLib::Patterns::Observer Class Reference

Object that gets notified when a given observable changes.

`#include <observable.hpp>`

Inheritance diagram for QuantLib::Patterns::Observer:



Public Methods

- **Observer** ()
- **Observer** (const Observer &)
- Observer & **operator=** (const Observer &)
- virtual ~**Observer** ()
- void **registerWith** (const Handle< Observable > &)
- void **unregisterWith** (const Handle< Observable > &)
- virtual void update ()=0

11.155.1 Member Function Documentation

11.155.1.1 virtual void update () [pure virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implemented in QuantLib::CashFlows::FloatingRateCoupon.

The documentation for this class was generated from the following file:

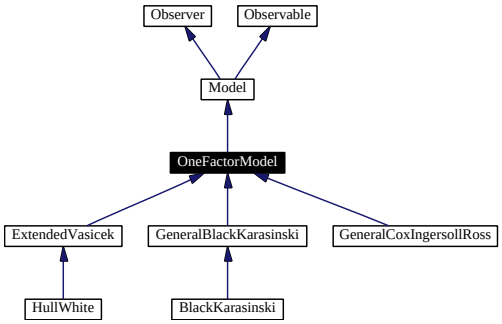
- observable.hpp

11.156 QuantLib::InterestRateModelling::OneFactorModel Class Reference

Single-factor short-rate model abstract class.

`#include <onefactormodel.hpp>`

Inheritance diagram for QuantLib::InterestRateModelling::OneFactorModel:



Public Methods

- **OneFactorModel** (Size nParameters, const RelinkableHandle< TermStructure > &termStructure)
- virtual ~**OneFactorModel** ()
- virtual Handle< ShortRateProcess > process () const=0

  returns the driving stochastic equation.

- virtual Handle< Lattices::Tree > tree (const TimeGrid &grid) const

  Return a recombining tree.

The documentation for this class was generated from the following files:

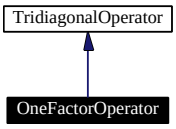
- onefactormodel.hpp
- onefactormodel.cpp

11.157 QuantLib::FiniteDifferences::OneFactorOperator Class Reference

Interest-rate single factor model differential operator.

`#include <onefactoroperator.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::OneFactorOperator:



Public Methods

- **OneFactorOperator** ()
- **OneFactorOperator** (const Array &grid, const Handle< InterestRateModelling::ShortRateProcess > &process)
- virtual ~**OneFactorOperator** ()

The documentation for this class was generated from the following file:

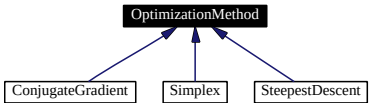
- onefactoroperator.hpp

11.158 QuantLib::Optimization::OptimizationMethod Class Reference

Optimization Method abstract class for unconstrained optimization pb.

`#include <optimizer.hpp>`

Inheritance diagram for QuantLib::Optimization::OptimizationMethod:



Public Methods

- **OptimizationMethod** ()
- virtual ~**OptimizationMethod** ()
- void setInitialValue (const Array &initialValue)

  Set initial value.
- void setEndCriteria (const OptimizationEndCriteria &endCriteria)

  Set optimization end criteria.
- int & iterationNumber ()

  current iteration number.
- OptimizationEndCriteria & endCriteria ()

  optimization end criteria.
- int & functionEvaluation ()

  number of evaluation of cost function.
- int & gradientEvaluation ()

  number of evaluation of cost function gradient.
- double & functionValue ()

  value of cost function.
- double & gradientNormValue ()

  value of cost function gradient norm.
- Array & x ()

  current value of the local minimum.
- Array & searchDirection ()

  current value of the search direction.
- virtual void minimize (OptimizationProblem &P)=0

  minimize the optimization problem P.

Protected Attributes

- Array initialValue_

  initial value of unknowns.

- int iterationNumber_

  current iteration step in the Optimization process.

- OptimizationEndCriteria endCriteria_

  optimization end criteria.

- int functionEvaluation_

  number of evaluation of cost function and its gradient.

- int gradientEvaluation_

  number of evaluation of cost function and its gradient.

- double functionValue_

  function and gradient norm values of the last step.

- double squaredNorm_

  function and gradient norm values of the last step.

- Array x_

  current values of the local minimum and the search direction.

- Array searchDirection_

  current values of the local minimum and the search direction.

The documentation for this class was generated from the following file:

- optimizer.hpp

11.159 QuantLib::Optimization::OptimizationProblem Class Reference

Unconstrained optimization pb.

`#include <optimizer.hpp>`

Public Methods

- OptimizationProblem (CostFunction &f, Constraint &c, OptimizationMethod &meth)
  default constructor.
- ~OptimizationProblem ()
  destructor.
- double value (const Array &x)
  call cost function computation and increment evaluation counter.
- void gradient (Array &grad_f, const Array &x)
  call cost function gradient computation and increment.
- double valueAndGradient (Array &grad_f, const Array &x)
  call cost function computation and it gradient.
- OptimizationMethod & optimisationMethod ()
  Unconstrained optimization method.
- Constraint & constraint ()
  constraint.
- CostFunction & **costFunction** ()
- void minimize ()
  Minimization.
- Array & **minimumValue** ()

Protected Attributes

- CostFunction & costFunction_
  Unconstrained cost function.
- Constraint & constraint_
  Constraint.
- OptimizationMethod & method_
  Unconstrained optimization method.

The documentation for this class was generated from the following file:

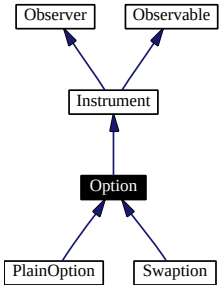
- optimizer.hpp

11.160 QuantLib::Option Class Reference

base option class.

`#include <option.hpp>`

Inheritance diagram for QuantLib::Option:



Public Types

- enum **Type** { **Call**, **Put**, **Straddle** }

Public Methods

- **Option** (const Handle< OptionPricingEngine > &engine, const std::string &isinCode="", const std::string &description="")
- virtual ~**Option** ()
- void **setPricingEngine** (const Handle< OptionPricingEngine > &)

Protected Methods

- virtual void **setupEngine** () const=0
- virtual void performCalculations () const

Protected Attributes

- Handle< OptionPricingEngine > **engine_**

11.160.1 Detailed Description

Examples:
DiscreteHedging.cpp.

11.160.2 Member Function Documentation

11.160.2.1 void performCalculations () const [protected, virtual]

Warning:
this method simply launches the engine and copies the returned value into NPV_. It does **not** set isExpired_. This should be taken care of by redefining this method in derived classes and calling this

implementation after checking for validity and only if the check succeeded.

Implements QuantLib::Instrument.

Reimplemented in QuantLib::Instruments::PlainOption.

The documentation for this class was generated from the following files:

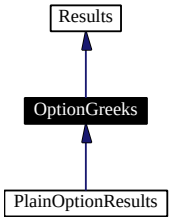
- option.hpp
- option.cpp

11.161 QuantLib::OptionGreeks Class Reference

option pricing results.

`#include <option.hpp>`

Inheritance diagram for QuantLib::OptionGreeks:



Public Methods

- **OptionGreeks** ()

Public Attributes

- double **delta**
- double **gamma**
- double **theta**
- double **vega**
- double **rho**
- double **dividendRho**

The documentation for this class was generated from the following file:

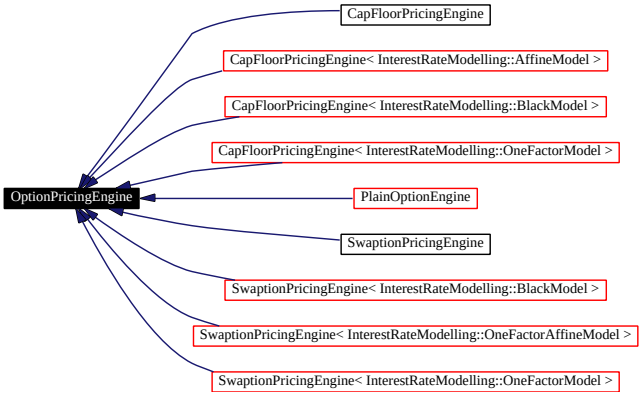
- option.hpp

11.162 QuantLib::OptionPricingEngine Class Reference

base class for option pricing engines.

`#include <option.hpp>`

Inheritance diagram for QuantLib::OptionPricingEngine:



Public Methods

- virtual ~**OptionPricingEngine** ()
- virtual Arguments * **parameters** ()=0
- virtual void **validateParameters** () const=0
- virtual void **calculate** () const=0
- virtual const Results * **results** () const=0

The documentation for this class was generated from the following file:

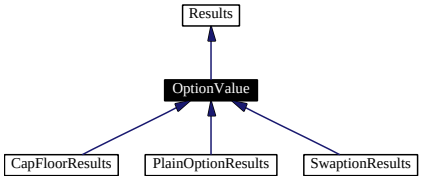
- option.hpp

11.163 QuantLib::OptionValue Class Reference

option pricing results.

`#include <option.hpp>`

Inheritance diagram for QuantLib::OptionValue:



Public Methods

- **OptionValue** ()

Public Attributes

- double **value**

11.163.1 Detailed Description

It must be noted that there's no result data specifying whether the option is expired. The expiry condition should be checked before calling the engine.

The documentation for this class was generated from the following file:

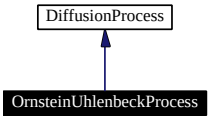
- option.hpp

11.164 QuantLib::OrnsteinUhlenbeckProcess Class Reference

Ornstein-Uhlenbeck process class.

`#include <diffusionprocess.hpp>`

Inheritance diagram for QuantLib::OrnsteinUhlenbeckProcess:



Public Methods

- **OrnsteinUhlenbeckProcess** (double speed, double vol, double x0=0.0)
- virtual double **drift** (Time t, double x) const
- virtual double **diffusion** (Time t, double x) const
- virtual double expectation (Time t0, double x0, Time dt) const

  Euler approximation of the expectation.

- virtual double variance (Time t0, double x0, Time dt) const

  Euler approximation of the variance.

11.164.1 Detailed Description

This class describes the Ornstein-Uhlenbeck process governed by

$$dx = -axdt + \sigma dW_t$$

.

The documentation for this class was generated from the following file:

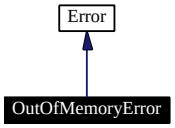
- diffusionprocess.hpp

11.165 QuantLib::OutOfMemoryError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::OutOfMemoryError:



Public Methods

- **OutOfMemoryError** (const std::string &whatClass=”unknown class”)

11.165.1 Detailed Description

Thrown upon failed allocation.

The documentation for this class was generated from the following file:

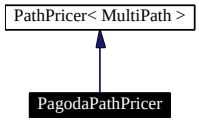
- errors.hpp

11.166 QuantLib::MonteCarlo::PagodaPathPricer Class Reference

multipath pricer for pagoda options.

`#include <pagodapathpricer.hpp>`

Inheritance diagram for QuantLib::MonteCarlo::PagodaPathPricer:



Public Methods

- **PagodaPathPricer** (const Array &underlying, double roof, DiscountFactor discount, bool useAntitheticVariance)
- double **operator()** (const MultiPath &path) const

11.166.1 Detailed Description

A pagoda option is a multi-asset asian option with a cap (the pagoda ”roof”). Given a portfolio of assets the payoff is the arithmetic average of the portfolio performance, with a maximum cap given by the roof.

The documentation for this class was generated from the following files:

- pagodapathpricer.hpp
- pagodapathpricer.cpp

11.167 QuantLib::MonteCarlo::Path Class Reference

single factor random walk.

`#include <path.hpp>`

Public Methods

- **Path** (Size size)
- **Path** (const std::vector< Time > &times, const Array &drift, const Array &diffusion)

inspectors

- double **operator[ ]** (int i) const
- Size **size** () const

read/write access to components

- const std::vector< Time > & **times** () const
- std::vector< Time > & **times** ()
- const Array & **drift** () const
- Array & **drift** ()
- const Array & **diffusion** () const
- Array & **diffusion** ()

11.167.1 Detailed Description

Todo:
make it time-aware

Examples:
DiscreteHedging.cpp.

The documentation for this class was generated from the following file:

- path.hpp

11.168 QuantLib::MonteCarlo::PathGenerator Class Template Reference

Generates random paths from a random number generator.

`#include <pathgenerator.hpp>`

Public Types

- typedef Sample< Path > **sample_type**

Public Methods

- **PathGenerator** (double drift, double variance, Time length, Size timeSteps, long seed=0)
- PathGenerator (double drift, double variance, const std::vector< Time > &times, long seed=0)

inspectors

- const sample_type & **next** () const
- Size **size** () const

11.168.1 Detailed Description

template<class RNG> class QuantLib::MonteCarlo::PathGenerator< RNG >

Todo:

add more general path generator with drift(S,t) and variance(S,t)

11.168.2 Constructor & Destructor Documentation

11.168.2.1 PathGenerator (double *drift*, double *variance*, const std::vector< Time > & *times*, long *seed* = 0)

Warning:

the initial time is assumed to be zero and must **not** be included in the passed vector

The documentation for this class was generated from the following file:

- pathgenerator.hpp

11.169 QuantLib::MonteCarlo::PathPricer Class Template Reference

base class for path pricers.

`#include <pathpricer.hpp>`

Public Methods

- **PathPricer** (DiscountFactor discount, bool useAntitheticVariance)
- virtual ~**PathPricer** ()
- virtual ValueType **operator()** (const PathType &path) const=0

Protected Attributes

- DiscountFactor **discount_**
- bool **useAntitheticVariance_**

11.169.1 Detailed Description

template<class PathType, class ValueType = double> class QuantLib::MonteCarlo::PathPricer< PathType, ValueType >

Given a path the value of an option is returned on that path.

Examples:
DiscreteHedging.cpp.

The documentation for this class was generated from the following file:

- pathpricer.hpp

11.170 QuantLib::Period Class Reference

Time period described by a number of a given time unit.

`#include <date.hpp>`

Public Methods

- **Period** ()
- **Period** (int n, TimeUnit units)
- int **length** () const
- TimeUnit **units** () const

The documentation for this class was generated from the following file:

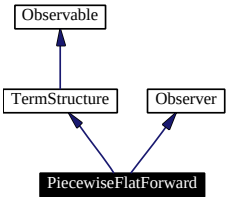
- date.hpp

11.171 QuantLib::TermStructures::PiecewiseFlatForward Class Reference

Piecewise flat forward term structure.

`#include <piecewiseflatforward.hpp>`

Inheritance diagram for QuantLib::TermStructures::PiecewiseFlatForward:



Public Methods

- **PiecewiseFlatForward** (Currency currency, const DayCounter &dayCounter, const Date &todaysDate, const Calendar &calendar, int settlementDays, const std::vector< Handle< RateHelper > > &instruments, double accuracy=1.0e-12)

TermStructure interface

- Currency currency () const
  returns the currency upon which the term structure is defined.
- DayCounter dayCounter () const
  returns the day counter.
- Date todaysDate () const
  returns today's date.
- int settlementDays () const
  returns the number of settlement days.
- Calendar calendar () const
  returns the calendar for settlement calculation.
- Date settlementDate () const
  returns the settlement date.
- const std::vector< Date > & **dates** () const
- Date maxDate () const
  returns the latest date for which the curve can return rates.
- Date minDate () const
  returns the earliest date for which the curve can return rates.
- const std::vector< Time > & **times** () const
- Time maxTime () const
  returns the latest date for which the curve can return rates.

- Time minTime () const

  returns the earliest time for which the curve can return rates.

Observer interface

- void update ()

Protected Methods

- Rate zeroYieldImpl (Time, bool extrapolate=false) const

  implements the actual zero yield calculation in derived classes.

- DiscountFactor discountImpl (Time, bool extrapolate=false) const

  implements the actual discount calculation in derived classes.

- Rate forwardImpl (Time, bool extrapolate=false) const

  implements the actual forward rate calculation in derived classes.

Friends

- class **FFObjFunction**

11.171.1 Detailed Description

This term structure is bootstrapped on a number of interest rate instruments which are passed as a vector of handles to RateHelper instances. Their maturities mark the boundaries of the flat forward segments.

The values of the forward rates for each segment are determined sequentially starting from the earliest period to the latest.

The value for each segment is chosen so that the instrument whose maturity marks the end of such segment is correctly repriced on the curve.

Warning:
The bootstrapping algorithm will raise an exception if any two instruments have the same maturity date.

11.171.2 Member Function Documentation

11.171.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following files:

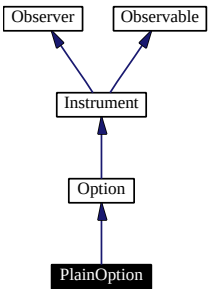
- piecewiseflatforward.hpp
- piecewiseflatforward.cpp

11.172 QuantLib::Instruments::PlainOption Class Reference

Plain (no dividends, no barriers) option on a single asset.

`#include <plainoption.hpp>`

Inheritance diagram for QuantLib::Instruments::PlainOption:



Public Methods

- **PlainOption** (Option::Type type, const RelinkableHandle< MarketElement > &underlying, double strike, const RelinkableHandle< TermStructure > &dividendYield, const RelinkableHandle< TermStructure > &riskFreeRate, const Date &exerciseDate, const RelinkableHandle< MarketElement > &volatility, const Handle< OptionPricingEngine > &engine, const std::string &isinCode="", const std::string &description="")
- double impliedVolatility (double targetValue, double accuracy=1.0e-4, Size maxEvaluations=100, double minVol=1.0e-4, double maxVol=4.0) const

greeks

- double **delta** () const
- double **gamma** () const
- double **theta** () const
- double **vega** () const
- double **rho** () const
- double **dividendRho** () const

Protected Methods

- void **setupEngine** () const
- void performCalculations () const

11.172.1 Member Function Documentation

11.172.1.1 double impliedVolatility (double *targetValue*, double *accuracy* = 1.0e-4, Size *maxEvaluations* = 100, double *minVol* = 1.0e-4, double *maxVol* = 4.0) const

Warning:

Options with a gamma that changes sign have values that are **not** monotonic in the volatility, e.g binary options. In these cases impliedVolatility can fail and in any case it is almost meaningless. Another possible source of failure is to have a targetValue that is not attainable with any volatility, e.g. a targetValue lower than the intrinsic value in the case of American options.

11.172.1.2 void performCalculations () const [protected, virtual]

Warning:
this method simply launches the engine and copies the returned value into NPV_. It does **not** set isExpired_. This should be taken care of by redefining this method in derived classes and calling this implementation after checking for validity and only if the check succeeded.

Reimplemented from QuantLib::Option.

The documentation for this class was generated from the following files:

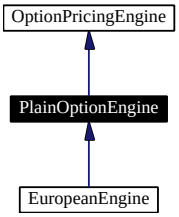
- plainoption.hpp
- plainoption.cpp

11.173 QuantLib::Pricers::PlainOptionEngine Class Reference

base class for plain option pricing engines.

`#include <plainoption.hpp>`

Inheritance diagram for QuantLib::Pricers::PlainOptionEngine:



Public Methods

- Arguments * **parameters** ()
- void **validateParameters** () const
- const Results * **results** () const

Protected Attributes

- Instruments::PlainOptionParameters **parameters**_
- Instruments::PlainOptionResults **results**_

11.173.1 Detailed Description

Derived engines only need to implement the `calculate()` method

The documentation for this class was generated from the following files:

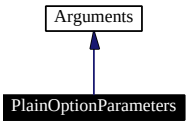
- plainoption.hpp
- plainoption.cpp

11.174 QuantLib::Instruments::PlainOptionParameters Class Reference

parameters for plain option calculation.

`#include <plainoption.hpp>`

Inheritance diagram for QuantLib::Instruments::PlainOptionParameters:



Public Methods

- **PlainOptionParameters** ()

Public Attributes

- Option::Type **type**
- double **underlying**
- double **strike**
- Spread **dividendYield**
- Rate **riskFreeRate**
- Time **residualTime**
- double **volatility**

The documentation for this class was generated from the following file:

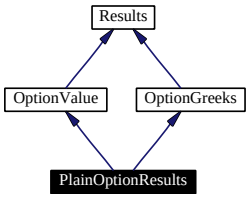
- plainoption.hpp

11.175 QuantLib::Instruments::PlainOptionResults Class Reference

results from plain option calculation.

`#include <plainoption.hpp>`

Inheritance diagram for QuantLib::Instruments::PlainOptionResults:



The documentation for this class was generated from the following file:

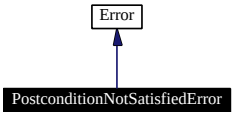
- plainoption.hpp

11.176 QuantLib::PostconditionNotSatisfiedError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::PostconditionNotSatisfiedError:



Public Methods

- **PostconditionNotSatisfiedError** (const std::string &what="")

11.176.1 Detailed Description

Thrown upon an unsatisfied postcondition.

The documentation for this class was generated from the following file:

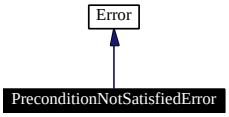
- errors.hpp

11.177 QuantLib::PreconditionNotSatisfiedError Class Reference

Specialized error.

`#include <errors.hpp>`

Inheritance diagram for QuantLib::PreconditionNotSatisfiedError:



Public Methods

- **PreconditionNotSatisfiedError** (const std::string &what="")

11.177.1 Detailed Description

Thrown upon an unsatisfied precondition.

The documentation for this class was generated from the following file:

- errors.hpp

11.178 QuantLib::Utilities::processing_iterator Class Template Reference

Iterator mapping a unary function to an underlying sequence.

`#include <processingiterator.hpp>`

Public Types

- typedef UnaryFunction::result_type **value_type**
- typedef const value_type * **pointer**
- typedef const value_type & **reference**

Public Methods

- **processing_iterator** (const Iterator &, const UnaryFunction &)

Dereferencing

- reference **operator** * () const
- pointer **operator** -> () const

Random access

- value_type **operator[ ]** (int) const

Increment and decrement

- processing_iterator & **operator++** ()
- processing_iterator **operator++** (int)
- processing_iterator & **operator–** ()
- processing_iterator **operator–** (int)
- processing_iterator & **operator+=** (difference_type)
- processing_iterator & **operator-=** (difference_type)
- processing_iterator **operator+** (difference_type)
- processing_iterator **operator-** (difference_type)

Difference

- difference_type **operator-** (const processing_iterator< Iterator, UnaryFunction > &)

Comparisons

- bool **operator==** (const processing_iterator< Iterator, UnaryFunction > &)
- bool **operator!=** (const processing_iterator< Iterator, UnaryFunction > &)
- bool **operator**< (const processing_iterator< Iterator, UnaryFunction > &)
- bool **operator**> (const processing_iterator< Iterator, UnaryFunction > &)
- bool **operator**<= (const processing_iterator< Iterator, UnaryFunction > &)
- bool **operator**>= (const processing_iterator< Iterator, UnaryFunction > &)

Public Attributes

- typedef< Iterator >::difference_type **difference_type**

Related Functions

(Note that these are not member functions.)

- processing_iterator< Iterator, UnaryFunction > make_processing_iterator (Iterator it, UnaryFunction p)

  helper function to create processing iterators.

11.178.1 Detailed Description

template<class Iterator, class UnaryFunction> class QuantLib::Utilities::processing_iterator< Iterator, UnaryFunction >

This iterator advances an underlying iterator and returns the values obtained by applying a unary function to the values such iterator points to.

This class was implemented based on Christopher Baus and Thomas Becker, *Custom Iterators for the STL*, included in the proceedings of the First Workshop on C++ Template Programming, Erfurt, Germany, 2000 (http://www.oonumerics.org/tmpw00/)

The documentation for this class was generated from the following file:

- processingiterator.hpp

11.179 QuantLib::RandomNumbers::RandomArrayGenerator Class Template Reference

Generates random arrays from a random number generator.

`#include <randomarraygenerator.hpp>`

Public Types

- typedef MonteCarlo::Sample< Array > **sample_type**

Public Methods

- **RandomArrayGenerator** (const Array &variance, long seed=0)
- **RandomArrayGenerator** (const Math::Matrix &covariance, long seed=0)
- const sample_type & **next** () const
- int **size** () const

template<class RNG> class QuantLib::RandomNumbers::RandomArrayGenerator< RNG >

The documentation for this class was generated from the following file:

- randomarraygenerator.hpp

11.180 QuantLib::RateFormatter Class Reference

Formats rates for output.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toString** (double rate, int precision=5)

11.180.1 Detailed Description

Formatting is in percentage form (xx.xxxxx%)

The documentation for this class was generated from the following files:

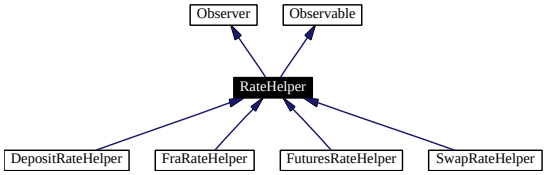
- dataformatters.hpp
- dataformatters.cpp

11.181 QuantLib::TermStructures::RateHelper Class Reference

base class for rate helpers.

`#include <ratehelpers.hpp>`

Inheritance diagram for QuantLib::TermStructures::RateHelper:



Public Methods

- **RateHelper** (const RelinkableHandle< MarketElement > &quote)
- **RateHelper** (double quote)
- virtual ~**RateHelper** ()

RateHelper interface

- double **quoteError** () const
- virtual double **impliedQuote** () const=0
- virtual DiscountFactor **discountGuess** () const
- virtual void setTermStructure (TermStructure *)

  sets the term structure to be used for pricing.

- virtual Date maturity () const=0

  maturity date.

Observer interface

- void update ()

Protected Attributes

- RelinkableHandle< MarketElement > **quote_**
- TermStructure * **termStructure_**

11.181.1 Detailed Description

This class provides an abstraction for the instruments used to bootstrap a term structure. It is advised that a rate helper for an instrument contains an instance of the actual instrument class to ensure consistancy between the algorithms used during bootstrapping and later instrument pricing. This is not yet fully enforced in the available rate helpers, though - only SwapRateHelper contains a Swap instrument for the time being.

11.181.2 Member Function Documentation

11.181.2.1 void setTermStructure (TermStructure *) [virtual]

Warning:

Being a pointer and not a Handle, the term structure is not guaranteed to remain allocated for the whole life of the rate helper. It is responsibility of the programmer to ensure that the pointer remains valid. It is advised that rate helpers be used only in term structure constructors, setting the term structure to **this**, i.e., the one being constructed.

Reimplemented in QuantLib::TermStructures::DepositRateHelper.

11.181.2.2 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following files:

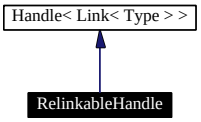
- ratehelpers.hpp
- ratehelpers.cpp

11.182 QuantLib::RelinkableHandle Class Template Reference

Globally accessible relinkable pointer.

`#include <relinkablehandle.hpp>`

Inheritance diagram for QuantLib::RelinkableHandle:



Public Methods

- RelinkableHandle (const Handle< Type > &h=Handle< Type >(), bool registerAsObserver=true)
- void linkTo (const Handle< Type > &h, bool registerAsObserver=true)
- const Handle< Type > & operator → () const

  dereferencing.

- bool isNull () const

  Checks if the contained handle points to anything.

11.182.1 Detailed Description

template<class Type> class QuantLib::RelinkableHandle< Type >

An instance of this class can be relinked to another Handle: such change will be propagated to all the copies of the instance.

Precondition:
Class "Type" must inherit from Observable

11.182.2 Constructor & Destructor Documentation

11.182.2.1 RelinkableHandle (const Handle< Type > & *h* = Handle< Type >(), bool *registerAsObserver* = true) [inline]

Warning:
see the documentation of `Link` for issues relatives to `registerAsObserver`.

11.182.3 Member Function Documentation

11.182.3.1 void linkTo (const Handle< Type > & *h*, bool *registerAsObserver* = true) [inline]

Warning:
see the documentation of `Link` for issues relatives to `registerAsObserver`.

The documentation for this class was generated from the following file:

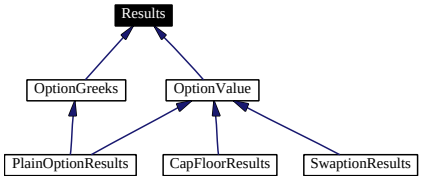
- relinkablehandle.hpp

11.183 QuantLib::Results Class Reference

base class for generic result groups.

`#include <argsandresults.hpp>`

Inheritance diagram for QuantLib::Results:



Public Methods

- virtual ~**Results** ()

The documentation for this class was generated from the following file:

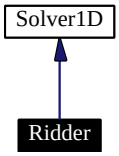
- argsandresults.hpp

11.184 QuantLib::Solvers1D::Ridder Class Reference

Ridder 1-D solver.

`#include <ridder.hpp>`

Inheritance diagram for QuantLib::Solvers1D::Ridder:



The documentation for this class was generated from the following files:

- ridder.hpp
- ridder.cpp

11.185 QuantLib::Math::RiskMeasures Class Reference

Interface for risk functions.

`#include <riskmeasures.hpp>`

Public Methods

- **RiskMeasures** ()
- double potentialUpside (double percentile, double mean, double std) const
- double valueAtRisk (double percentile, double mean, double std) const
- double expectedShortfall (double percentile, double mean, double std) const
- double **shortfall** (double target, double mean, double std) const
- double **averageShortfall** (double target, double mean, double std) const

11.185.1 Member Function Documentation

11.185.1.1 double potentialUpside (double *percentile*, double *mean*, double *std*) const [inline]

Precondition:
percentile must be in range 90%-100%

11.185.1.2 double valueAtRisk (double *percentile*, double *mean*, double *std*) const [inline]

Precondition:
percentile must be in range 90%-100%

11.185.1.3 double expectedShortfall (double *percentile*, double *mean*, double *std*) const [inline]

Precondition:
percentile must be in range 90%-100%

The documentation for this class was generated from the following file:

- riskmeasures.hpp

11.186 QuantLib::RiskStatistics Class Reference

Risk analysis tool.

`#include <riskstatistics.hpp>`

Public Methods

Inspectors

- Size **samples** () const
- double **weightSum** () const
- double **mean** () const
- double **variance** () const
- double **standardDeviation** () const
- double **errorEstimate** () const
- double **skewness** () const
- double **kurtosis** () const
- double **min** () const
- double **max** () const
- double potentialUpside (double percentile) const

  returns the Potential-Up-Front at a given percentile.

- double valueAtRisk (double percentile) const

  returns the Value-At-Risk at a given percentile.

- double expectedShortfall (double percentile) const

  returns the Expected Shortfall at a given percentile.

- double shortfall (double target) const

  returns the Shortfall (observations below target).

- double averageShortfall (double target) const

  returns the Average Shortfall (averaged shortfallness).

Modifiers

- void add (double value, double weight=1.0)
- template<class DataIterator> void **addSequence** (DataIterator begin, DataIterator end)
- template<class DataIterator, class WeightIterator> void addSequence (DataIterator begin, DataIterator end, WeightIterator wbegin)

  adds a sequence of data to the set, each with its weight.

- void **reset** ()

11.186.1 Detailed Description

It can accumulate a set of data and return risk quantities as Value-At-Risk, Expected Shortfall, Shortfall, Average Shortfall, plus statistic quantitities as mean, variance, std. deviation, skewness, kurtosis.

11.186.2 Member Function Documentation

11.186.2.1 void add (double *value*, double *weight* = 1.0) [inline]

Precondition:
weights must be positive or null

The documentation for this class was generated from the following file:

- riskstatistics.hpp

11.187 QuantLib::MonteCarlo::Sample Struct Template Reference

weighted sample.

`#include <sample.hpp>`

Public Methods

- **Sample** (const T &value, double weight)

Public Attributes

- T **value**
- double **weight**

template<class T> struct QuantLib::MonteCarlo::Sample< T >

The documentation for this struct was generated from the following file:

- sample.hpp

11.188 QuantLib::Scheduler Class Reference

Date scheduler.

`#include <scheduler.hpp>`

Public Types

- typedef std::vector< Date >::const_iterator **const_iterator**

Public Methods

- **Scheduler** (const Calendar &calendar, const Date &startDate, const Date &endDate, int frequency, RollingConvention rollingConvention, bool isAdjusted, const Date &stubDate=Date())
- Size **size** () const
- const Date & **date** (int i) const
- bool **isRegular** (Size i) const
- const_iterator **begin** () const
- const_iterator **end** () const

The documentation for this class was generated from the following files:

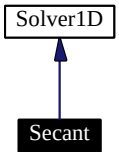
- scheduler.hpp
- scheduler.cpp

11.189 QuantLib::Solvers1D::Secant Class Reference

secant 1-D solver.

`#include <secant.hpp>`

Inheritance diagram for QuantLib::Solvers1D::Secant:



The documentation for this class was generated from the following files:

- secant.hpp
- secant.cpp

11.190 QuantLib::Math::SegmentIntegral Class Reference

Integral of a one-dimensional function.

`#include <segmentintegral.hpp>`

Public Methods

- **SegmentIntegral** (Size intervals)
- double **operator()** (const ObjectiveFunction &f, double a, double b) const

11.190.1 Detailed Description

Warning:
the use of this class is not recommended since it will be redesigned in one of the next minor releases.

Todo:
Redesign as a template function.

Examples:
EuropeanOption.cpp.

The documentation for this class was generated from the following files:

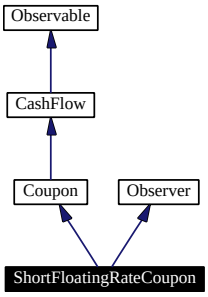
- segmentintegral.hpp
- segmentintegral.cpp

11.191 QuantLib::CashFlows::ShortFloatingRateCoupon Class Reference

short coupon at par on a term structure.

`#include <shortfloatingcoupon.hpp>`

Inheritance diagram for QuantLib::CashFlows::ShortFloatingRateCoupon:



Public Methods

- **ShortFloatingRateCoupon** (double nominal, const Handle< Indexes::Xibor > &index, const RelinkableHandle< TermStructure > &termStructure, const Date &startDate, const Date &endDate, int fixingDays, Spread spread=0.0, const Date &refPeriodStart=Date(), const Date &refPeriodEnd=Date())

CashFlow interface

- double amount () const
  returns the amount of the cash flow.

Coupon interface

- double accruedAmount (const Date &) const
  accrued amount at the given date.

Inspectors

- const Handle< Indexes::Xibor > & **index** () const
- Rate **fixing** () const
- Spread **spread** () const

Observer interface

- void update ()

11.191.1 Detailed Description

Warning:

This class does not perform any date adjustment, i.e., the start and end date passed upon construction should be already rolled to a business day.

11.191.2 Member Function Documentation

11.191.2.1 double amount () const [virtual]

Note:
The amount is not discounted, i.e., it is the actual amount paid at the cash flow date.

Implements QuantLib::CashFlow.

11.191.2.2 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following files:

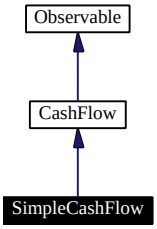
- shortfloatingcoupon.hpp
- shortfloatingcoupon.cpp

11.192 QuantLib::CashFlows::SimpleCashFlow Class Reference

Predetermined cash flow.

`#include <simplecashflow.hpp>`

Inheritance diagram for QuantLib::CashFlows::SimpleCashFlow:



Public Methods

- **SimpleCashFlow** (double amount, const Date &date)
- double amount () const

  returns the amount of the cash flow.

- Date date () const

  returns the date at which the cash flow is settled.

11.192.1 Detailed Description

This cash flow pays a predetermined amount at a given date.

11.192.2 Member Function Documentation

11.192.2.1 double amount () const [inline, virtual]

Note:
The amount is not discounted, i.e., it is the actual amount paid at the cash flow date.

Implements QuantLib::CashFlow.

The documentation for this class was generated from the following file:

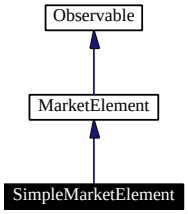
- simplecashflow.hpp

11.193 QuantLib::SimpleMarketElement Class Reference

market element returning a stored value.

`#include <marketelement.hpp>`

Inheritance diagram for QuantLib::SimpleMarketElement:



Public Methods

- **SimpleMarketElement** (double value)

Market element interface

- double value () const
  returns the current value.

Modifiers

- void **setValue** (double value)

The documentation for this class was generated from the following file:

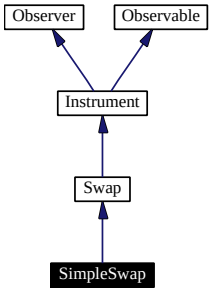
- marketelement.hpp

11.194 QuantLib::Instruments::SimpleSwap Class Reference

Simple fixed-rate vs Libor swap.

`#include <simpleswap.hpp>`

Inheritance diagram for QuantLib::Instruments::SimpleSwap:



Public Methods

- **SimpleSwap** (bool payFixedRate, const Date &startDate, int n, TimeUnit units, const Calendar &calendar, RollingConvention rollingConvention, double nominal, int fixedFrequency, Rate fixedRate, bool fixedIsAdjusted, const DayCounter &fixedDayCount, int floatingFrequency, const Handle< Indexes::Xibor > &index, int indexFixingDays, Spread spread, const RelinkableHandle< TermStructure > &termStructure, const std::string &isinCode="", const std::string &description="")

- Rate **fairRate** () const
- Spread **spread** () const
- double **fixedLegBPS** () const
- double **floatingLegBPS** () const
- Rate **fixedRate** () const
- double **nominal** () const
- const Date & **maturity** () const
- bool **payFixedRate** () const
- const std::vector< Handle< CashFlow > > & **fixedLeg** () const
- const std::vector< Handle< CashFlow > > & **floatingLeg** () const

The documentation for this class was generated from the following file:

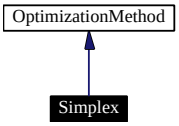
- simpleswap.hpp

11.195 QuantLib::Optimization::Simplex Class Reference

Multi-dimensionnal Simplex class.

`#include <simplex.hpp>`

Inheritance diagram for QuantLib::Optimization::Simplex:



Public Methods

- Simplex (double lambda, double tol)
- virtual ~**Simplex** ()
- double **extrapolate** (OptimizationProblem &P, Size iHighest, double factor)
- virtual void minimize (OptimizationProblem &P)

  minimize the optimization problem P.

11.195.1 Constructor & Destructor Documentation

11.195.1.1 Simplex (double *lambda*, double *tol*) `[inline]`

Constructor taking as input λ as the characteristic length and tol as the precision

The documentation for this class was generated from the following files:

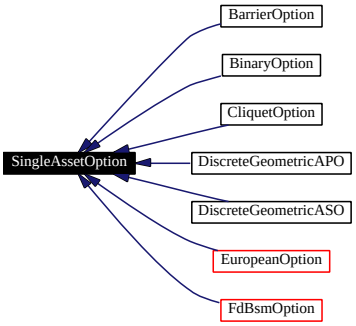
- simplex.hpp
- simplex.cpp

11.196 QuantLib::Pricers::SingleAssetOption Class Reference

Black-Scholes-Merton option.

`#include <singleassetoption.hpp>`

Inheritance diagram for QuantLib::Pricers::SingleAssetOption:



Public Methods

- **SingleAssetOption** (Option::Type type, double underlying, double strike, Spread dividendYield, Rate riskFreeRate, Time residualTime, double volatility)
- virtual ~**SingleAssetOption** ()
- virtual void **setVolatility** (double newVolatility)
- virtual void **setRiskFreeRate** (Rate newRate)
- virtual void **setDividendYield** (Rate newDividendYield)
- virtual double **value** () const=0
- virtual double **delta** () const=0
- virtual double **gamma** () const=0
- virtual double **theta** () const=0
- virtual double **vega** () const
- virtual double **rho** () const
- virtual double **dividendRho** () const
- double impliedVolatility (double targetValue, double accuracy=1e-4, Size maxEvaluations=100, double minVol=0.0001, double maxVol=4.0) const
- virtual Handle< SingleAssetOption > **clone** () const=0

Protected Attributes

- Option::Type **type**_
- double **underlying**_
- double **strike**_
- Spread **dividendYield**_
- Rate **riskFreeRate**_
- Time **residualTime**_
- double **volatility**_
- bool **hasBeenCalculated**_
- double **rho**_
- double **dividendRho**_

- double **vega_**
- bool **rhoComputed_**
- bool **dividendRhoComputed_**
- bool **vegaComputed_**

Static Protected Attributes

- const double **dVolMultiplier_** = 0.0001
- const double **dRMultiplier_** = 0.0001

Friends

- class **VolatilityFunction**

11.196.1 Member Function Documentation

11.196.1.1 double impliedVolatility (double *targetValue*, double *accuracy* = 1e-4, Size *maxEvaluations* = 100, double *minVol* = 0.0001, double *maxVol* = 4.0) const

Warning:

Options with a gamma that changes sign have values that are **not** monotonic in the volatility, e.g binary options. In these cases impliedVolatility can fail and in any case is meaningless. Another possible source of failure is to have a targetValue that is not attainable with any volatility, e.g. a targetValue lower than the intrinsic value in the case of American options.

The documentation for this class was generated from the following files:

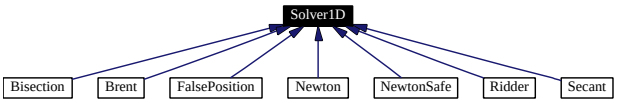
- singleassetoption.hpp
- singleassetoption.cpp

11.197 QuantLib::Solver1D Class Reference

Abstract base class for 1-D solvers.

`#include <solver1d.hpp>`

Inheritance diagram for QuantLib::Solver1D:



Public Methods

- **Solver1D** ()
- virtual ~**Solver1D** ()

Modifiers

- double solve (const ObjectiveFunction &f, double xAccuracy, double guess, double step) const
- double solve (const ObjectiveFunction &f, double xAccuracy, double guess, double xMin, double xMax) const
- void setMaxEvaluations (int evaluations)
- void setLowBound (double lowBound)
  sets the lower bound for the function domain.
- void setHiBound (double hiBound)
  sets the upper bound for the function domain.

Protected Methods

- virtual double solve_ (const ObjectiveFunction &f, double xAccuracy) const=0

Protected Attributes

- double **root**_
- double **xMin**_
- double **xMax**_
- double **fxMin**_
- double **fxMax**_
- int **maxEvaluations**_
- int **evaluationNumber**_

11.197.1 Member Function Documentation

11.197.1.1 double solve (const ObjectiveFunction & *f*, double *xAccuracy*, double *guess*, double *step*) const

This method returns the zero of the ObjectiveFunction f, determined with the given accuracy (i.e., x is considered a zero if $|f(x)| < accuracy$). This method contains a bracketing routine to which an initial guess must be supplied as well as a step used to scan the range of the possible bracketing values.

11.197.1.2 double solve (const ObjectiveFunction & *f*, double *xAccuracy*, double *guess*, double *xMin*, double *xMax*) const

This method returns the zero of the ObjectiveFunction f, determined with the given accuracy (i.e., x is considered a zero if $|f(x)| < accuracy$). An initial guess must be supplied, as well as two values which must bracket the zero (i.e., either $f(x_{min}) > 0$ && $f(x_{max}) < 0$, or $f(x_{min}) < 0$ && $f(x_{max}) > 0$ must be true).

11.197.1.3 void setMaxEvaluations (int *evaluations*) [inline]

This method sets the maximum number of function evaluations for the bracketing routine. An Error is thrown if a bracket is not found after this number of evaluations.

11.197.1.4 virtual double solve_ (const ObjectiveFunction & *f*, double *xAccuracy*) const [protected, pure virtual]

This method must be implemented in derived classes and contains the actual code which searches for the zeroes of the ObjectiveFunction. It assumes that:

- **xMin**_ and **xMax**_ form a valid bracket;
- **fxMin**_ and **fxMax**_ contain the values of the function in **xMin**_ and **xMax**_;
- **root**_ was initialized to a valid initial guess.

Implemented in QuantLib::Solvers1D::Bisection.

The documentation for this class was generated from the following files:

- solver1d.hpp
- solver1d.cpp

11.198 QuantLib::Math::Statistics Class Reference

Statistic tool.

`#include <statistics.hpp>`

Public Methods

- **Statistics** ()

Inspectors

- Size samples () const
  number of samples collected.
- double weightSum () const
  sum of data weights.
- double mean () const
- double variance () const
- double standardDeviation () const
- double downsideVariance () const
- double downsideDeviation () const
- double errorEstimate () const
- double skewness () const
- double kurtosis () const
- double min () const
- double max () const

Modifiers

- void add (double value, double weight=1.0)
  adds a datum to the set, possibly with a weight.
- template<class DataIterator> void addSequence (DataIterator begin, DataIterator end)
  adds a sequence of data to the set.
- template<class DataIterator, class WeightIterator> void addSequence (DataIterator begin, DataIterator end, WeightIterator wbegin)
  adds a sequence of data to the set, each with its weight.
- void reset ()
  resets the data to a null set.

11.198.1 Detailed Description

It can accumulate a set of data and return statistic quantities as mean, variance, std. deviation, skewness, and kurtosis.

Examples:
DiscreteHedging.cpp.

11.198.2 Member Function Documentation

11.198.2.1 double mean () const [inline]

returns the mean, defined as

$$\langle x \rangle = \frac{\sum w_i x_i}{\sum w_i}.$$

11.198.2.2 double variance () const [inline]

returns the variance, defined as

$$\frac{N}{N-1}\left\langle (x - \langle x \rangle)^2 \right\rangle.$$

11.198.2.3 double standardDeviation () const [inline]

returns the standard deviation σ, defined as the square root of the variance.

11.198.2.4 double downsideVariance () const [inline]

returns the downside variance, defined as

$$\frac{N}{N-1} \times \frac{\sum_{i=1}^{N} \theta \times x_i^2}{\sum_{i=1}^{N} w_i}$$

, where θ = 0 if x $>$ 0 and θ =1 if x $<$0

11.198.2.5 double downsideDeviation () const [inline]

returns the downside deviation, defined as the square root of the downside variance.

11.198.2.6 double errorEstimate () const [inline]

returns the error estimate ϵ, defined as the square root of the ratio of the variance to the number of samples.

11.198.2.7 double skewness () const [inline]

returns the skewness, defined as

$$\frac{N^2}{(N-1)(N-2)} \frac{\left\langle (x - \langle x \rangle)^3 \right\rangle}{\sigma^3}.$$

The above evaluates to 0 for a Gaussian distribution.

11.198.2.8 double kurtosis () const [inline]

returns the excess kurtosis, defined as

$$\frac{N(N+1)}{(N-1)(N-2)(N-3)}\frac{\left\langle (x-\langle x\rangle)^4\right\rangle}{\sigma^4}-\frac{3(N-1)^2}{(N-2)(N-3)}.$$

The above evaluates to 0 for a Gaussian distribution.

11.198.2.9 double min () const [inline]

returns the minimum sample value

11.198.2.10 double max () const [inline]

returns the maximum sample value

11.198.2.11 void add (double *value*, double *weight* = 1.0) [inline]

Precondition:
weights must be positive or null

The documentation for this class was generated from the following files:

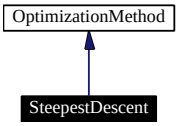
- statistics.hpp
- statistics.cpp

11.199 QuantLib::Optimization::SteepestDescent Class Reference

Multi-dimensionnal Steepest Descend class.

`#include <steepestdescent.hpp>`

Inheritance diagram for QuantLib::Optimization::SteepestDescent:



Public Methods

- SteepestDescent ()
  default default constructor (msvc bug).
- SteepestDescent (const Handle< LineSearch > &lineSearch)
  default constructor.
- virtual ~SteepestDescent ()
  destructor.
- virtual void minimize (OptimizationProblem &P)
  minimize the optimization problem P.

11.199.1 Detailed Description

User has to provide line-search method and optimization end criteria

search direction $= -f'(x)$

The documentation for this class was generated from the following files:

- steepestdescent.hpp
- steepestdescent.cpp

11.200 QuantLib::FiniteDifferences::StepCondition Class Template Reference

condition to be applied at every time step.

`#include <stepcondition.hpp>`

Public Methods

- virtual ~**StepCondition** ()
- virtual void **applyTo** (arrayType &a, Time t) const=0

template<class arrayType> class QuantLib::FiniteDifferences::StepCondition< arrayType >

The documentation for this class was generated from the following file:

- stepcondition.hpp

11.201 QuantLib::Utilities::stepping_iterator Class Template Reference

Iterator advancing in constant steps.

`#include <steppingiterator.hpp>`

Public Methods

- **stepping_iterator** (const RandomAccessIterator &, difference_type step)

Dereferencing

- reference **operator** $*$ () const
- pointer **operator** $\rightarrow$ () const

Random access

- reference **operator[ ]** (int) const

Increment and decrement

- stepping_iterator & **operator++** ()
- stepping_iterator **operator++** (int)
- stepping_iterator & **operator–** ()
- stepping_iterator **operator–** (int)
- stepping_iterator & **operator+=** (difference_type)
- stepping_iterator & **operator-=** (difference_type)
- stepping_iterator< RandomAccessIterator > **operator+** (difference_type)
- stepping_iterator< RandomAccessIterator > **operator-** (difference_type)

Difference

- difference_type **operator-** (const stepping_iterator< RandomAccessIterator > &)

Comparisons

- bool **operator==** (const stepping_iterator< RandomAccessIterator > &)
- bool **operator!=** (const stepping_iterator< RandomAccessIterator > &)
- bool **operator**< (const stepping_iterator< RandomAccessIterator > &)
- bool **operator**> (const stepping_iterator< RandomAccessIterator > &)
- bool **operator**<= (const stepping_iterator< RandomAccessIterator > &)
- bool **operator**>= (const stepping_iterator< RandomAccessIterator > &)

Public Attributes

- typedef< RandomAccessIterator >::difference_type **difference_type**
- typedef< RandomAccessIterator >::pointer **pointer**
- typedef< RandomAccessIterator >::reference **reference**

Related Functions

(Note that these are not member functions.)

- stepping_iterator< Iterator > make_stepping_iterator (Iterator it, typename stepping_iterator< Iterator >::difference_type step)

  helper function to create stepping iterators.

11.201.1 Detailed Description

template<class RandomAccessIterator> class QuantLib::Utilities::stepping_iterator< RandomAccessIterator >

This iterator advances an underlying random access iterator in steps of n positions, where n is an integer given upon construction.

The documentation for this class was generated from the following file:

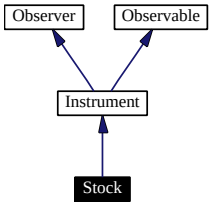
- steppingiterator.hpp

11.202 QuantLib::Instruments::Stock Class Reference

Simple stock class.

`#include <stock.hpp>`

Inheritance diagram for QuantLib::Instruments::Stock:



Public Methods

- **Stock** (const RelinkableHandle< MarketElement > &quote, const std::string &isinCode, const std::string &description)

Protected Methods

- void performCalculations () const

11.202.1 Member Function Documentation

11.202.1.1 void performCalculations () const [protected, virtual]

This method must implement any calculations which must be (re)done in order to calculate the NPV of the instrument.

Implements QuantLib::Instrument.

The documentation for this class was generated from the following files:

- stock.hpp
- stock.cpp

11.203 QuantLib::StringFormatter Class Reference

Formats strings as lower- or uppercase.

`#include <dataformatters.hpp>`

Static Public Methods

- std::string **toLowercase** (const std::string &s)
- std::string **toUppercase** (const std::string &s)

The documentation for this class was generated from the following files:

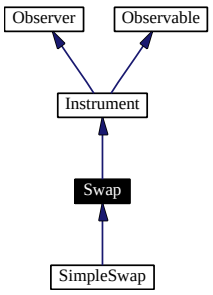
- dataformatters.hpp
- dataformatters.cpp

11.204 QuantLib::Instruments::Swap Class Reference

Interest rate swap.

`#include <swap.hpp>`

Inheritance diagram for QuantLib::Instruments::Swap:



Public Methods

- **Swap** (const std::vector< Handle< CashFlow > > &firstLeg, const std::vector< Handle< CashFlow > > &secondLeg, const RelinkableHandle< TermStructure > &termStructure, const std::string &isinCode="", const std::string &description="")
- double **firstLegBPS** () const
- double **secondLegBPS** () const

Protected Methods

- void performCalculations () const

Protected Attributes

- std::vector< Handle< CashFlow > > **firstLeg_**
- std::vector< Handle< CashFlow > > **secondLeg_**
- RelinkableHandle< TermStructure > **termStructure_**
- double **firstLegBPS_**
- double **secondLegBPS_**

11.204.1 Detailed Description

The cash flows belonging to the first leg are payed; the ones belonging to the first leg are received.

11.204.2 Member Function Documentation

11.204.2.1 void performCalculations () const [protected, virtual]

This method must implement any calculations which must be (re)done in order to calculate the NPV of the instrument.

Implements QuantLib::Instrument.

The documentation for this class was generated from the following files:

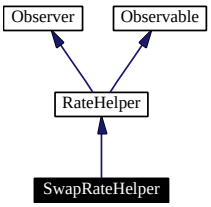
- swap.hpp
- swap.cpp

11.205 QuantLib::TermStructures::SwapRateHelper Class Reference

swap rate.

`#include <ratehelpers.hpp>`

Inheritance diagram for QuantLib::TermStructures::SwapRateHelper:



Public Methods

- **SwapRateHelper** (const RelinkableHandle< MarketElement > &rate, int settlementDays, int lengthInYears, const Calendar &calendar, RollingConvention convention, int fixedFrequency, bool fixedIsAdjusted, const DayCounter &fixedDayCount, int floatingFrequency)
- **SwapRateHelper** (double rate, int settlementDays, int lengthInYears, const Calendar &calendar, RollingConvention convention, int fixedFrequency, bool fixedIsAdjusted, const DayCounter &fixedDayCount, int floatingFrequency)
- double **impliedQuote** () const
- Date maturity () const

  maturity date.

- void setTermStructure (TermStructure *)

  sets the term structure to be used for pricing.

Protected Attributes

- int **settlementDays_**
- int **lengthInYears_**
- Calendar **calendar_**
- RollingConvention **convention_**
- int **fixedFrequency_**
- int **floatingFrequency_**
- bool **fixedIsAdjusted_**
- DayCounter **fixedDayCount_**
- Date **settlement_**
- Handle< Instruments::SimpleSwap > **swap_**
- RelinkableHandle< TermStructure > **termStructureHandle_**

11.205.1 Detailed Description

Warning:

This class assumes that today's date does not change between calls of setTermStructure().

11.205.2 Member Function Documentation

11.205.2.1 void setTermStructure (TermStructure *) [virtual]

Warning:

Being a pointer and not a Handle, the term structure is not guaranteed to remain allocated for the whole life of the rate helper. It is responsibility of the programmer to ensure that the pointer remains valid. It is advised that rate helpers be used only in term structure constructors, setting the term structure to **this**, i.e., the one being constructed.

Reimplemented from QuantLib::TermStructures::RateHelper.

The documentation for this class was generated from the following files:

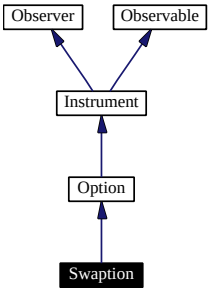
- ratehelpers.hpp
- ratehelpers.cpp

11.206 QuantLib::Instruments::Swaption Class Reference

Swaption class.

`#include <swaption.hpp>`

Inheritance diagram for QuantLib::Instruments::Swaption:



Public Methods

- **Swaption** (const Handle< SimpleSwap > &swap, const Exercise &exercise, const RelinkableHandle< TermStructure > &termStructure, const Handle< OptionPricingEngine > &engine)

Protected Methods

- void performCalculations () const
- void **setupEngine** () const

11.206.1 Member Function Documentation

11.206.1.1 void performCalculations () const [protected, virtual]

Warning:
this method simply launches the engine and copies the returned value into NPV_. It does **not** set isExpired_. This should be taken care of by redefining this method in derived classes and calling this implementation after checking for validity and only if the check succeeded.

Reimplemented from QuantLib::Option.

The documentation for this class was generated from the following files:

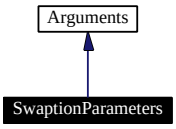
- swaption.hpp
- swaption.cpp

11.207 QuantLib::Instruments::SwaptionParameters Class Reference

parameters for swaption calculation.

`#include <swaption.hpp>`

Inheritance diagram for QuantLib::Instruments::SwaptionParameters:



Public Methods

- **SwaptionParameters** ()
- void **validate** () const

Public Attributes

- bool **payFixed**
- Rate **fairRate**
- Rate **fixedRate**
- double **fixedBPS**
- std::vector< Time > **fixedPayTimes**
- std::vector< double > **fixedCoupons**
- std::vector< Time > **floatingResetTimes**
- std::vector< Time > **floatingPayTimes**
- std::vector< double > **nominals**
- Exercise::Type **exerciseType**
- std::vector< Time > **exerciseTimes**

The documentation for this class was generated from the following file:

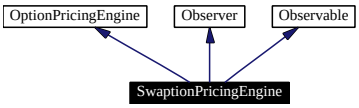
- swaption.hpp

11.208 QuantLib::Pricers::SwaptionPricingEngine Class Template Reference

base class for swaption pricing engines.

`#include <swaption.hpp>`

Inheritance diagram for QuantLib::Pricers::SwaptionPricingEngine:



Public Methods

- **SwaptionPricingEngine** ()
- **SwaptionPricingEngine** (const Handle< ModelType > &model)
- Arguments * **parameters** ()
- const Results * **results** () const
- void **validateParameters** () const
- void **setModel** (const Handle< ModelType > &model)
- void update ()

Protected Attributes

- Instruments::SwaptionParameters **parameters_**
- Instruments::SwaptionResults **results_**
- Handle< ModelType > **model_**

11.208.1 Detailed Description

template<class ModelType> class QuantLib::Pricers::SwaptionPricingEngine< ModelType >

Derived engines only need to implement the `calculate()` method

11.208.2 Member Function Documentation

11.208.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

The documentation for this class was generated from the following file:

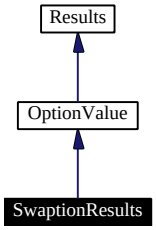
- swaption.hpp

11.209 QuantLib::Instruments::SwaptionResults Class Reference

results from swaption calculation.

`#include <swaption.hpp>`

Inheritance diagram for QuantLib::Instruments::SwaptionResults:



The documentation for this class was generated from the following file:

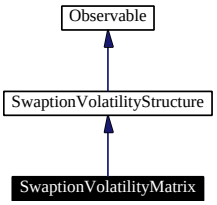
- swaption.hpp

11.210 QuantLib::Volatilities::SwaptionVolatilityMatrix Class Reference

Swaption at-the-money volatility matrix.

`#include <swaptionvolmatrix.hpp>`

Inheritance diagram for QuantLib::Volatilities::SwaptionVolatilityMatrix:



Public Methods

- **SwaptionVolatilityMatrix** (const Date &todaysDate, const std::vector< Date > &exerciseDates, const std::vector< Period > &lengths, const Math::Matrix &volatilities, const DayCounter &dayCounter=DayCounters::Thirty360())
- Date todaysDate () const

  returns today's date.

- DayCounter dayCounter () const

  returns the day counter used for internal date/time conversions.

- const std::vector< Date > & **exerciseDates** () const
- const std::vector< Period > & **lengths** () const

11.210.1 Detailed Description

This class provides the at-the-money volatility for a given swaption by interpolating a volatility matrix whose elements are the market volatilities of a set of swaption with given exercise date and length.

Todo:

Either add correct copy behavior or inhibit copy. Right now, a copied instance would end up with its own copy of the exercise date and length vector but an interpolation pointing to the original ones.

The documentation for this class was generated from the following file:

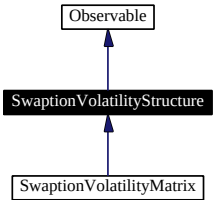
- swaptionvolmatrix.hpp

11.211 QuantLib::SwaptionVolatilityStructure Class Reference

Swaption volatility structure.

`#include <swaptionvolstructure.hpp>`

Inheritance diagram for QuantLib::SwaptionVolatilityStructure:



Public Methods

- virtual ~**SwaptionVolatilityStructure** ()
- virtual Date todaysDate () const=0

  returns today's date.

- virtual DayCounter dayCounter () const=0

  returns the day counter used for internal date/time conversions.

- double volatility (const Date &start, const Period &length, Rate strike) const

  returns the volatility for a given starting date and length.

- double volatility (Time start, Time length, Rate strike) const

  returns the volatility for a given starting time and length.

Protected Methods

- virtual double volatilityImpl (Time start, Time length, Rate strike) const=0

  implements the actual volatility calculation in derived classes.

11.211.1 Detailed Description

This class is purely abstract and defines the interface of concrete swaption volatility structures which will be derived from this one.

The documentation for this class was generated from the following file:

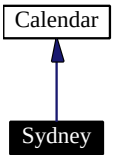
- swaptionvolstructure.hpp

11.212 QuantLib::Calendars::Sydney Class Reference

Sydney, calendar (New South Wales, Australia).

`#include <sydney.hpp>`

Inheritance diagram for QuantLib::Calendars::Sydney:



Public Methods

- **Sydney** ()

11.212.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st (possibly moved to Monday or Tuesday)
- Day after New Year's Day, January 2st (possibly moved to Monday or Tuesday)
- Anniversary Day, Monday nearest January 22nd
- Waitangi Day. February 6th
- Good Friday
- Easter Monday
- ANZAC Day. April 25th
- Queen's Birthday, first Monday in June
- Labour Day, fourth Monday in October
- Christmas, December 25th (possibly moved to Monday or Tuesday)
- Boxing Day, December 26th (possibly moved to Monday or Tuesday)

Note:

The holiday rules for Sydney were documented by David Gilbert for IDB (`http://www.jrefinery.com/ibd/`)

The documentation for this class was generated from the following file:

- sydney.hpp

11.213 QuantLib::Math::SymmetricSchurDecomposition Class Reference

symmetric threshold Jacobi algorithm.

`#include <symmetricschurdecomposition.hpp>`

Public Methods

- **SymmetricSchurDecomposition** (Matrix &s)
- Array **eigenvalues** () const
- Matrix **eigenvectors** () const

11.213.1 Detailed Description

Given a real symmetric matrix S, the Schur decomposition finds the eigenvalues and eigenvectors of S. If D is the diagonal matrix formed by the eigenvalues and U the unitarian matrix of th eigenvector we can write the Schur decomposition as

$$S = U \cdot D \cdot U^T ,$$

where $\cdot$ is the standard matrix product and ^{T} is the transpose operator. This class implements the Schur decomposition using the symmetric threshold Jacobi algorithm. For details on the different Jacobi transfomations you can start from the great book on matrix computations by Golub and Van Loan: Matrix computation, second edition The Johns Hopkins University Press

The documentation for this class was generated from the following files:

- symmetricschurdecomposition.hpp
- symmetricschurdecomposition.cpp

11.214 QuantLib::Calendars::TARGET Class Reference

TARGET calendar.

`#include <target.hpp>`

Inheritance diagram for QuantLib::Calendars::TARGET:

Public Methods

- **TARGET** ()

11.214.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Good Friday
- Easter Monday
- Labour Day, May 1st
- Christmas, December 25th
- Day of Goodwill, December 26th

The documentation for this class was generated from the following file:

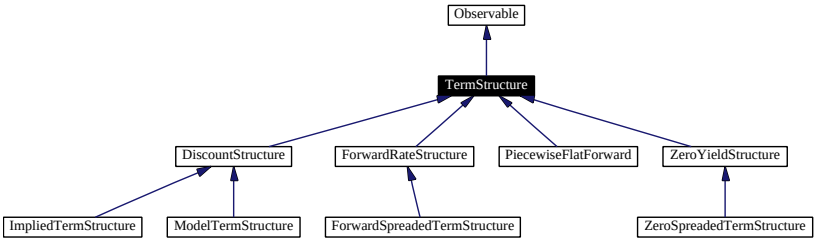
- target.hpp

11.215 QuantLib::TermStructure Class Reference

Term structure.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::TermStructure:



Public Methods

- virtual ~**TermStructure** ()

Rates and discount

- Rate zeroYield (const Date &, bool extrapolate=false) const
  zero yield rate at a given date.
- Rate zeroYield (Time, bool extrapolate=false) const
  zero yield rate at a given time from settlement.
- DiscountFactor discount (const Date &, bool extrapolate=false) const
  discount factor at a given date.
- DiscountFactor discount (Time, bool extrapolate=false) const
  discount factor at a given time from settlement.
- Rate forward (const Date &, bool extrapolate=false) const
  instantaneous forward rate at a given date.
- Rate forward (Time, bool extrapolate=false) const
  instantaneous forward rate at a given time from settlement.

Dates

- virtual Date todaysDate () const=0
  returns today's date.
- virtual int settlementDays () const=0
  returns the number of settlement days.
- virtual Calendar calendar () const=0
  returns the calendar for settlement calculation.

- virtual DayCounter dayCounter () const=0
  returns the day counter.
- virtual Date settlementDate () const=0
  returns the settlement date.
- virtual Date minDate () const=0
  returns the earliest date for which the curve can return rates.
- virtual Date maxDate () const=0
  returns the latest date for which the curve can return rates.
- virtual Time minTime () const=0
  returns the earliest time for which the curve can return rates.
- virtual Time maxTime () const=0
  returns the latest date for which the curve can return rates.

Other inspectors

- virtual Currency currency () const=0
  returns the currency upon which the term structure is defined.

Protected Methods

- virtual Rate zeroYieldImpl (Time, bool extrapolate=false) const=0
  implements the actual zero yield calculation in derived classes.
- virtual DiscountFactor discountImpl (Time, bool extrapolate=false) const=0
  implements the actual discount calculation in derived classes.
- virtual Rate forwardImpl (Time, bool extrapolate=false) const=0
  implements the actual forward rate calculation in derived classes.

11.215.1 Detailed Description

This abstract class defines the interface of concrete rate structures which will be derived from this one.

The documentation for this class was generated from the following file:

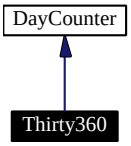
- termstructure.hpp

11.216 QuantLib::DayCounters::Thirty360 Class Reference

30/360 day count convention.

`#include <thirty360.hpp>`

Inheritance diagram for QuantLib::DayCounters::Thirty360:



Public Types

- enum **Convention** { **USA**, **European**, **Italian** }

Public Methods

- **Thirty360** (Convention c=Thirty360::USA)

11.216.1 Detailed Description

The day count can be calculated according to US, European, or Italian conventions.

US (NASD) convention: if the starting date is the 31st of a month, it becomes equal to the 30th of the same month. If the ending date is the 31st of a month and the starting date is earlier than the 30th of a month, the ending date becomes equal to the 1st of the next month, otherwise the ending date becomes equal to the 30th of the same month.

European convention: starting dates or ending dates that occur on the 31st of a month become equal to the 30th of the same month.

Italian convention: starting dates or ending dates that occur on February and are grater than 27 become equal to 30 for computational sake.

The documentation for this class was generated from the following files:

- thirty360.hpp
- thirty360.cpp

11.217 QuantLib::TimeGrid Class Reference

time grid class.

`#include <grid.hpp>`

Public Methods

- **TimeGrid** ()
- **TimeGrid** (const std::list< Time > &times, Size steps)
- Size **findIndex** (Time t) const
- Time **dt** (Size i) const

The documentation for this class was generated from the following file:

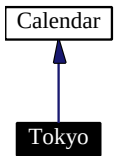
- grid.hpp

11.218 QuantLib::Calendars::Tokyo Class Reference

Tokyo calendar.

`#include <tokyo.hpp>`

Inheritance diagram for QuantLib::Calendars::Tokyo:



Public Methods

- **Tokyo** ()

11.218.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Bank Holiday, January 2nd
- Bank Holiday, January 3rd
- Coming of Age Day, 2nd Monday in January
- National Foundation Day, February 11th
- Vernal Equinox
- Greenery Day, April 29th
- Constitution Memorial Day, May 3rd
- Holiday for a Nation, May 4th
- Children's Day, May 5th
- Marine Day, July 20th
- Respect for the Aged Day, September 15th
- Autumnal Equinox
- Health and Sports Day, 2nd Monday in October
- National Culture Day, November 3rd
- Labor Thanksgiving Day, November 23rd
- Emperor's Birthday, December 23rd
- Bank Holiday, December 31st

Holidays falling on a Sunday are observed on the Monday following except for the Bank Holidays associated with the New Year

Todo:
insert actual rules for Equinoxes

The documentation for this class was generated from the following file:

- tokyo.hpp

11.219 QuantLib::Calendars::Toronto Class Reference

Toronto calendar.

`#include <toronto.hpp>`

Inheritance diagram for QuantLib::Calendars::Toronto:

Public Methods

- **Toronto** ()

11.219.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st (possibly moved to Monday)
- Good Friday
- Easter Monday
- Victoria Day, The Monday on or preceding 24 May
- Canada Day, July 1st
- Provincial Holiday, first Monday of August
- Labour Day, first Monday of September
- Thanksgiving Day, second Monday of October
- Remembrance Day, November 11th
- Christmas, December 25th
- Boxing Day, December 26th

The documentation for this class was generated from the following file:

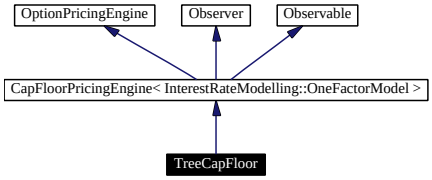
- toronto.hpp

11.220 QuantLib::Pricers::TreeCapFloor Class Reference

Cap/Floor priced in a tree.

`#include <treecapfloor.hpp>`

Inheritance diagram for QuantLib::Pricers::TreeCapFloor:



Public Methods

- **TreeCapFloor** (const Handle< InterestRateModelling::OneFactorModel > &model, Size timeSteps)
- **TreeCapFloor** (const Handle< Lattices::Tree > &tree)
- void **calculate** () const

The documentation for this class was generated from the following files:

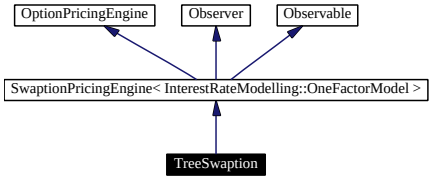
- treecapfloor.hpp
- treecapfloor.cpp

11.221 QuantLib::Pricers::TreeSwaption Class Reference

Swaption priced in a tree.

`#include <treeswaption.hpp>`

Inheritance diagram for QuantLib::Pricers::TreeSwaption:



Public Methods

- **TreeSwaption** (const Handle< InterestRateModelling::OneFactorModel > &model, Size timeSteps)
- **TreeSwaption** (const Handle< Lattices::Tree > &tree)
- void **calculate** () const

The documentation for this class was generated from the following files:

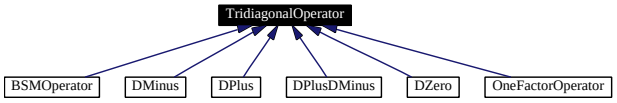
- treeswaption.hpp
- treeswaption.cpp

11.222 QuantLib::FiniteDifferences::TridiagonalOperator Class Reference

Base implementation for tridiagonal operator.

`#include <tridiagonaloperator.hpp>`

Inheritance diagram for QuantLib::FiniteDifferences::TridiagonalOperator:



Operator interface

- Array applyTo (const Array &v) const
  apply operator to a given array.
- Array solveFor (const Array &rhs) const
  solve linear system for a given right-hand side.
- Array SOR (const Array &rhs, double tol) const
  solve linear system with SOR approach.
- TridiagonalOperator identity (Size size)
  identity instance.

Public Types

- typedef Array **arrayType**

Public Methods

- **TridiagonalOperator** (Size size=0)
- **TridiagonalOperator** (const Array &low, const Array &mid, const Array &high)

Inspectors

- Size **size** () const
- bool **isTimeDependent** ()

Modifiers

- void **setLowerBC** (const BoundaryCondition &bc)
- void **setUpperBC** (const BoundaryCondition &bc)
- void **setFirstRow** (double, double)
- void **setMidRow** (Size, double, double, double)
- void **setMidRows** (double, double, double)
- void **setLastRow** (double, double)
- void **setTime** (Time t)

Protected Attributes

- Array **diagonal_**
- Array **belowDiagonal_**
- Array **aboveDiagonal_**
- BoundaryCondition **lowerBC_**
- BoundaryCondition **upperBC_**
- Handle< TimeSetter > **timeSetter_**

Friends

- TridiagonalOperator **operator+** (const TridiagonalOperator &)
- TridiagonalOperator **operator-** (const TridiagonalOperator &)
- TridiagonalOperator **operator+** (const TridiagonalOperator &, const TridiagonalOperator &)
- TridiagonalOperator **operator-** (const TridiagonalOperator &, const TridiagonalOperator &)
- TridiagonalOperator **operator** * (double, const TridiagonalOperator &)
- TridiagonalOperator **operator** * (const TridiagonalOperator &, double)
- TridiagonalOperator **operator/** (const TridiagonalOperator &, double)

11.222.1 Detailed Description

Warning:

to use real time-dependant algebra, you must overload the corresponding operators in the inheriting time-dependent class

The documentation for this class was generated from the following files:

- tridiagonaloperator.hpp
- tridiagonaloperator.cpp

11.223 QuantLib::FiniteDifferences::TridiagonalOperator::TimeSetter Class Reference

encapsulation of time-setting logic.

`#include <tridiagonaloperator.hpp>`

Public Methods

- virtual ~**TimeSetter** ()
- virtual void **setTime** (Time t, TridiagonalOperator &L) const=0

The documentation for this class was generated from the following file:

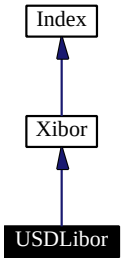
- tridiagonaloperator.hpp

11.224 QuantLib::Indexes::USDLibor Class Reference

USD Libor index.

`#include <usdlibor.hpp>`

Inheritance diagram for QuantLib::Indexes::USDLibor:



Public Methods

- **USDLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

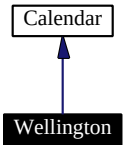
- usdlibor.hpp

11.225 QuantLib::Calendars::Wellington Class Reference

Wellington calendar.

`#include <wellington.hpp>`

Inheritance diagram for QuantLib::Calendars::Wellington:



Public Methods

- **Wellington** ()

11.225.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st (possibly moved to Monday or Tuesday)
- Day after New Year's Day, January 2st (possibly moved to Monday or Tuesday)
- Anniversary Day, Monday nearest January 22nd
- Waitangi Day. February 6th
- Good Friday
- Easter Monday
- ANZAC Day. April 25th
- Queen's Birthday, first Monday in June
- Labour Day, fourth Monday in October
- Christmas, December 25th (possibly moved to Monday or Tuesday)
- Boxing Day, December 26th (possibly moved to Monday or Tuesday)

Note:

The holiday rules for Wellington were documented by David Gilbert for IDB (`http://www.jrefinery.com/ibd/`)

The documentation for this class was generated from the following file:

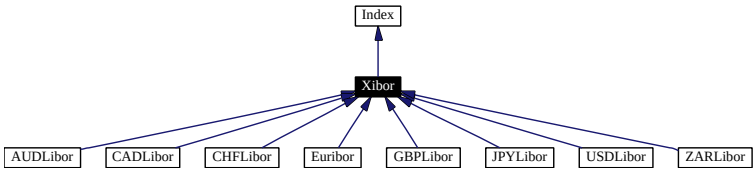
- wellington.hpp

11.226 QuantLib::Indexes::Xibor Class Reference

base class for libor indexes.

`#include <xibor.hpp>`

Inheritance diagram for QuantLib::Indexes::Xibor:



Public Methods

- **Xibor** (const std::string &familyName, int n, TimeUnit units, int settlementDays, Currency currency, const Calendar &calendar, bool isAdjusted, RollingConvention rollingConvention, const DayCounter &dayCounter, const RelinkableHandle< TermStructure > &h)

Index interface

- Rate fixing (const Date &fixingDate) const
  returns the fixing at the given date.

Inspectors

- std::string name () const
  Returns the name of the index.
- Period **tenor** () const
- int **settlementDays** () const
- Currency **currency** () const
- Calendar **calendar** () const
- bool **isAdjusted** () const
- RollingConvention **rollingConvention** () const
- DayCounter **dayCounter** () const

11.226.1 Member Function Documentation

11.226.1.1 Rate fixing (const Date & *fixingDate*) const `[virtual]`

Note:
any date passed as arguments must be a value date, i.e., the real calendar date advanced by a number of settlement days.

Implements QuantLib::Index.

11.226.1.2 std::string name () const [virtual]

Warning:
This method is used for output and comparison between indexes. It is **not** meant to be used for writing switch-on-type code.

Implements QuantLib::Index.

The documentation for this class was generated from the following files:

- xibor.hpp
- xibor.cpp

11.227 QuantLib::Indexes::XiborManager Class Reference

global repository for libor histories.

`#include <xibormanager.hpp>`

Static Public Methods

- void **setHistory** (const std::string &name, const History &)
- const History & **getHistory** (const std::string &name)
- bool **hasHistory** (const std::string &name)
- std::vector< std::string > **histories** ()

The documentation for this class was generated from the following files:

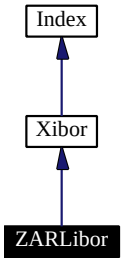
- xibormanager.hpp
- xibormanager.cpp

11.228 QuantLib::Indexes::ZARLibor Class Reference

ZAR Libor index (also known as JIBAR, check settlement days).

`#include <zarlibor.hpp>`

Inheritance diagram for QuantLib::Indexes::ZARLibor:



Public Methods

- **ZARLibor** (int n, TimeUnit units, const RelinkableHandle< TermStructure > &h)

The documentation for this class was generated from the following file:

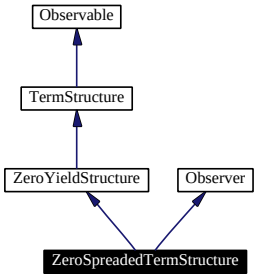
- zarlibor.hpp

11.229 QuantLib::ZeroSpreadedTermStructure Class Reference

Term structure with an added spread on the zero yield rate.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::ZeroSpreadedTermStructure:



Public Methods

- **ZeroSpreadedTermStructure** (const RelinkableHandle< TermStructure > &, const RelinkableHandle< MarketElement > &spread)

TermStructure interface

- Currency currency () const
  returns the currency upon which the term structure is defined.
- Date todaysDate () const
  returns today's date.
- int settlementDays () const
  returns the number of settlement days.
- Calendar calendar () const
  returns the calendar for settlement calculation.
- DayCounter dayCounter () const
  returns the day counter.
- Date settlementDate () const
  returns the settlement date.
- Date maxDate () const
  returns the latest date for which the curve can return rates.
- Date minDate () const
  returns the earliest date for which the curve can return rates.
- Time maxTime () const
  returns the latest date for which the curve can return rates.
- Time minTime () const

returns the earliest time for which the curve can return rates.

Observer interface

- void update ()

Protected Methods

- Rate zeroYieldImpl (Time, bool extrapolate=false) const

  returns the spreaded zero yield rate.

- Rate forwardImpl (Time, bool extrapolate=false) const

  returns the spreaded forward rate.

11.229.1 Detailed Description

Note:

This term structure will remain linked to the original structure, i.e., any changes in the latter will be reflected in this structure as well.

11.229.2 Member Function Documentation

11.229.2.1 void update () [inline, virtual]

This method must be implemented in derived classes. An instance of Observer does not call this method directly: instead, it will be called by the observables the instance registered with when they need to notify any changes.

Implements QuantLib::Patterns::Observer.

11.229.2.2 Rate forwardImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Warning:

This method must disappear should the spread become a curve

Reimplemented from QuantLib::ZeroYieldStructure.

The documentation for this class was generated from the following file:

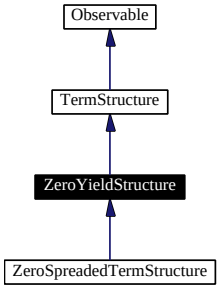
- termstructure.hpp

11.230 QuantLib::ZeroYieldStructure Class Reference

Zero yield term structure.

`#include <termstructure.hpp>`

Inheritance diagram for QuantLib::ZeroYieldStructure:



Public Methods

- virtual ~**ZeroYieldStructure** ()

Protected Methods

- DiscountFactor discountImpl (Time, bool extrapolate=false) const
- Rate forwardImpl (Time, bool extrapolate=false) const

11.230.1 Detailed Description

This abstract class acts as an adapter to TermStructure allowing the programmer to implement only the `zeroYield(Time)` method in derived classes.

11.230.2 Member Function Documentation

11.230.2.1 DiscountFactor discountImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the discount factor for the given date calculating it from the zero yield.

Implements QuantLib::TermStructure.

11.230.2.2 Rate forwardImpl (Time, bool *extrapolate* = false) const [inline, protected, virtual]

Returns the instantaneous forward rate for the given date calculating it from the zero yield.

Implements QuantLib::TermStructure.

Reimplemented in QuantLib::ZeroSpreadedTermStructure.

The documentation for this class was generated from the following file:

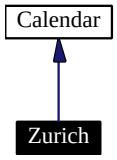
- termstructure.hpp

11.231 QuantLib::Calendars::Zurich Class Reference

Zurich calendar.

`#include <zurich.hpp>`

Inheritance diagram for QuantLib::Calendars::Zurich:



Public Methods

- **Zurich** ()

11.231.1 Detailed Description

Holidays:

- Saturdays
- Sundays
- New Year's Day, January 1st
- Berchtoldstag, January 2nd
- Good Friday
- Easter Monday
- Ascension Day
- Whit Monday
- Labour Day, May 1st
- National Day, August 1st
- Christmas, December 25th
- St. Stephen's Day, December 26th

The documentation for this class was generated from the following file:

- zurich.hpp

Chapter 12

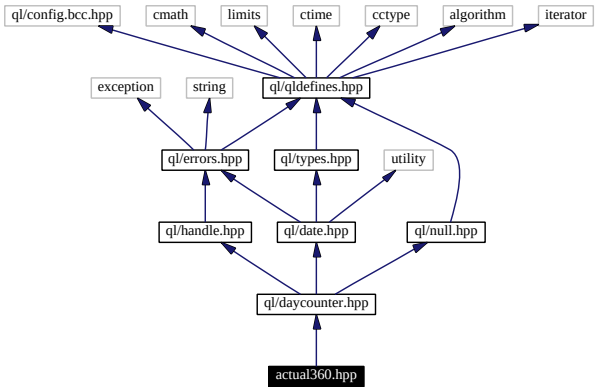
QuantLib File Documentation

12.1 actual360.hpp File Reference

act/360 day counter.

`#include <ql/daycounter.hpp>`

Include dependency graph for actual360.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.1.1 Detailed Description

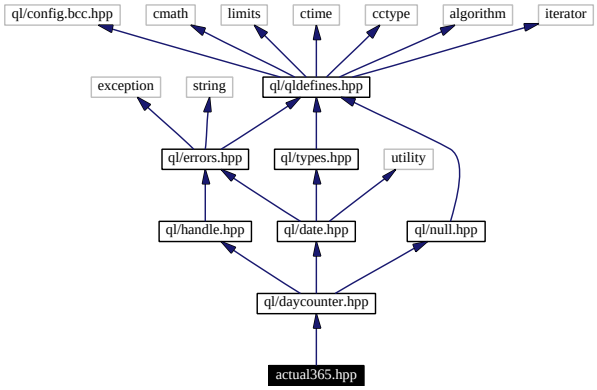
Full path:
ql/DayCounters/actual360.hpp

12.2 actual365.hpp File Reference

act/365 day counter.

`#include <ql/daycounter.hpp>`

Include dependency graph for actual365.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.2.1 Detailed Description

Full path:
ql/DayCounters/actual365.hpp

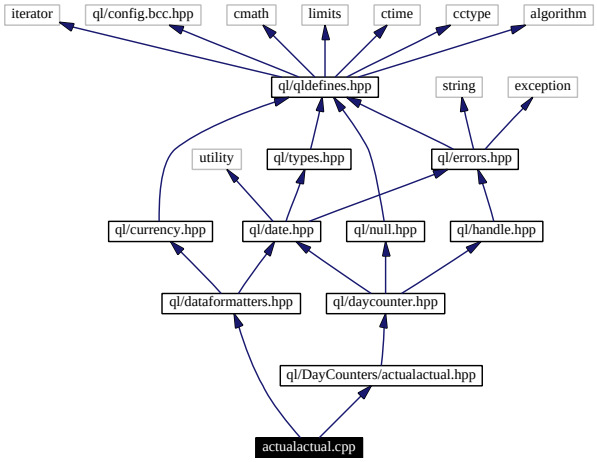
12.3 actualactual.cpp File Reference

act/act day counters.

`#include <ql/DayCounters/actualactual.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for actualactual.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.3.1 Detailed Description

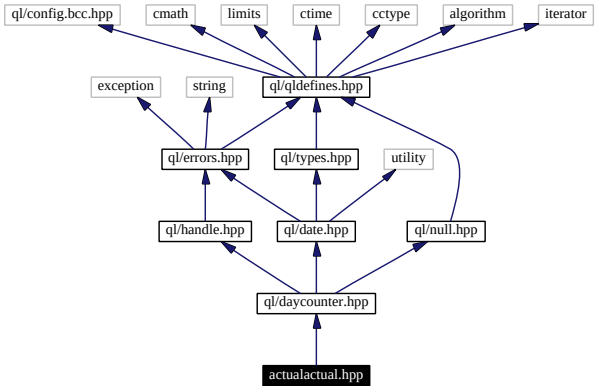
Full path:
ql/DayCounters/actualactual.cpp

12.4 actualactual.hpp File Reference

act/act day counters.

`#include <ql/daycounter.hpp>`

Include dependency graph for actualactual.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.4.1 Detailed Description

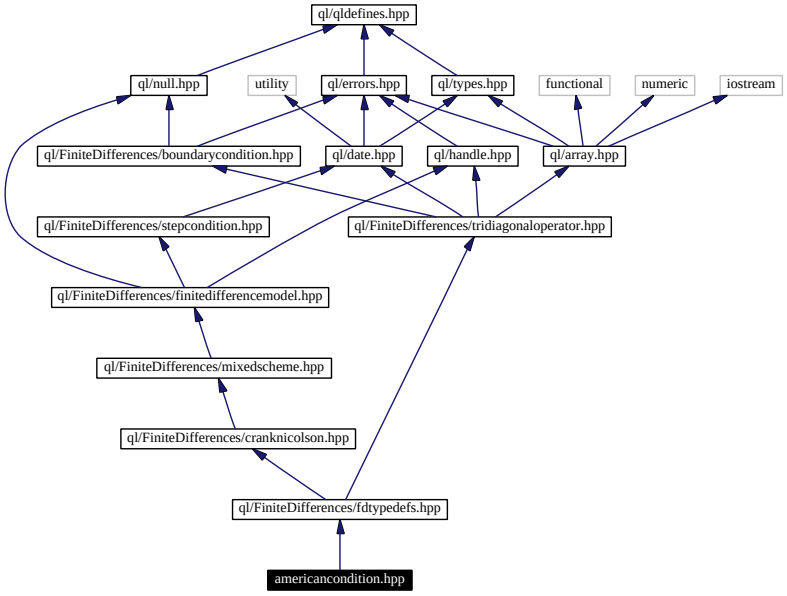
Full path:
ql/DayCounters/actualactual.hpp

12.5 americancondition.hpp File Reference

american option exercise condition.

`#include <ql/FiniteDifferences/fdtypedefs.hpp>`

Include dependency graph for americancondition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.5.1 Detailed Description

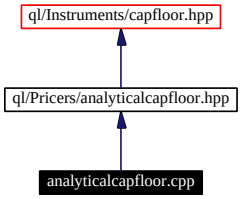
Full path:
ql/FiniteDifferences/americancondition.hpp

12.6 analyticalcapfloor.cpp File Reference

Analytical pricer for caps/floors.

`#include "ql/Pricers/analyticalcapfloor.hpp"`

Include dependency graph for analyticalcapfloor.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.6.1 Detailed Description

Full path:
ql/Pricers/analyticalcapfloor.cpp

12.7 analyticalcapfloor.hpp File Reference

Analytical pricer for caps/floors.

`#include <ql/Instruments/capfloor.hpp>`

Include dependency graph for analyticalcapfloor.hpp:

Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.7.1 Detailed Description

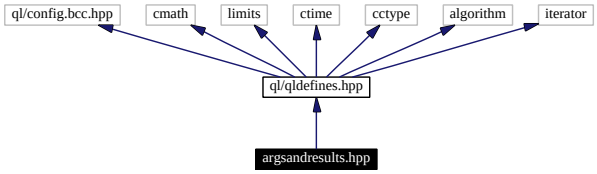
Full path:
ql/Pricers/analyticalcapfloor.hpp

12.8 argsandresults.hpp File Reference

Base classes for generic arguments and results.

`#include <ql/qldefines.hpp>`

Include dependency graph for argsandresults.hpp:



Namespaces

- namespace QuantLib

12.8.1 Detailed Description

Full path:
ql/argsandresults.hpp

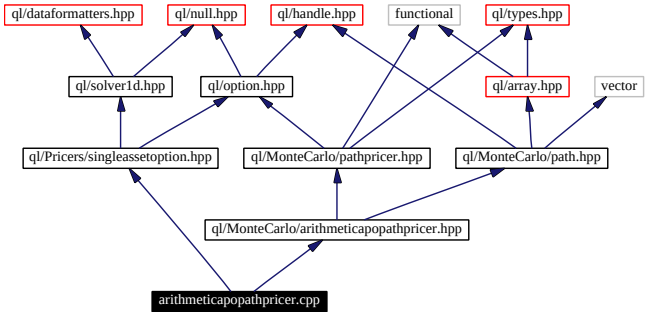
12.9 arithmeticapopathpricer.cpp File Reference

arithmetic average price option path pricer.

`#include <ql/MonteCarlo/arithmeticapopathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for arithmeticapopathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.9.1 Detailed Description

Full path:
ql/MonteCarlo/arithmeticapopathpricer.cpp

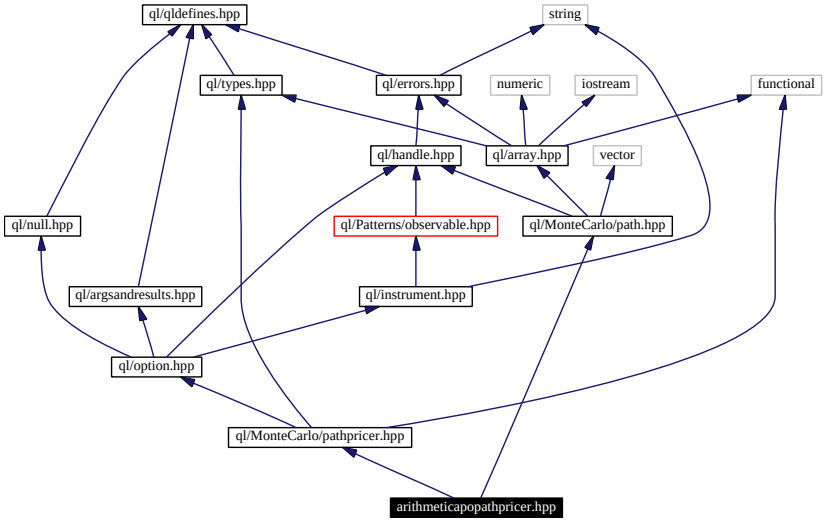
12.10 arithmeticapopathpricer.hpp File Reference

arithmetic average price option path pricer.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/path.hpp>`

Include dependency graph for arithmeticapopathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.10.1 Detailed Description

Full path:
ql/MonteCarlo/arithmeticapopathpricer.hpp

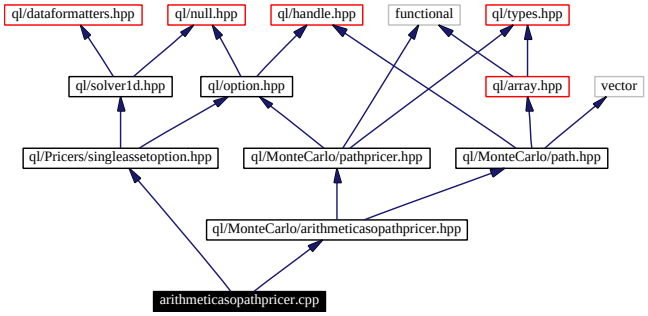
12.11 arithmeticasopathpricer.cpp File Reference

arithmetic average strike option path pricer.

`#include <ql/MonteCarlo/arithmeticasopathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for arithmeticasopathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.11.1 Detailed Description

Full path:
ql/MonteCarlo/arithmeticasopathpricer.cpp

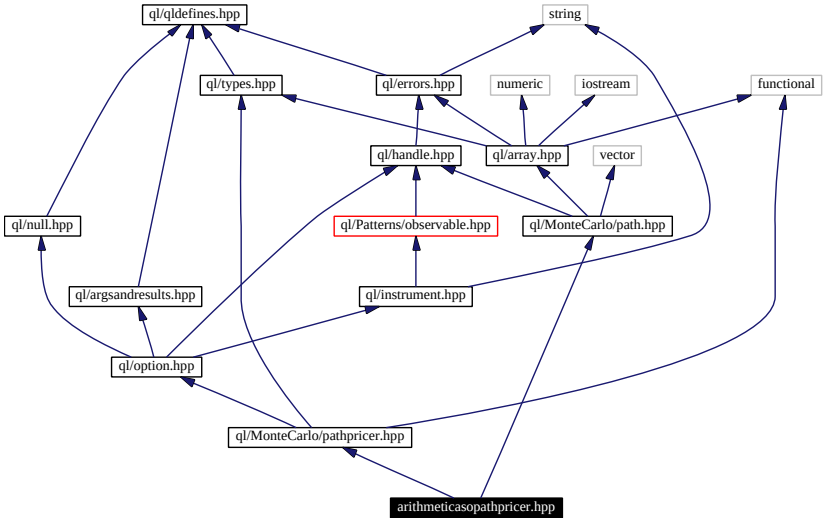
12.12 arithmeticasopathpricer.hpp File Reference

arithmetic average strike option path pricer.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/path.hpp>`

Include dependency graph for arithmeticasopathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.12.1 Detailed Description

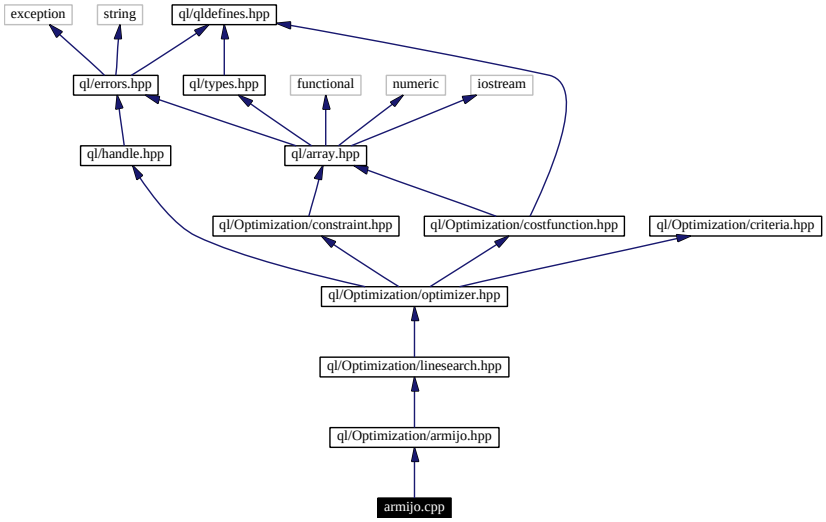
Full path:
ql/MonteCarlo/arithmeticasopathpricer.hpp

12.13 armijo.cpp File Reference

Armijo line-search class.

`#include "ql/Optimization/armijo.hpp"`

Include dependency graph for armijo.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.13.1 Detailed Description

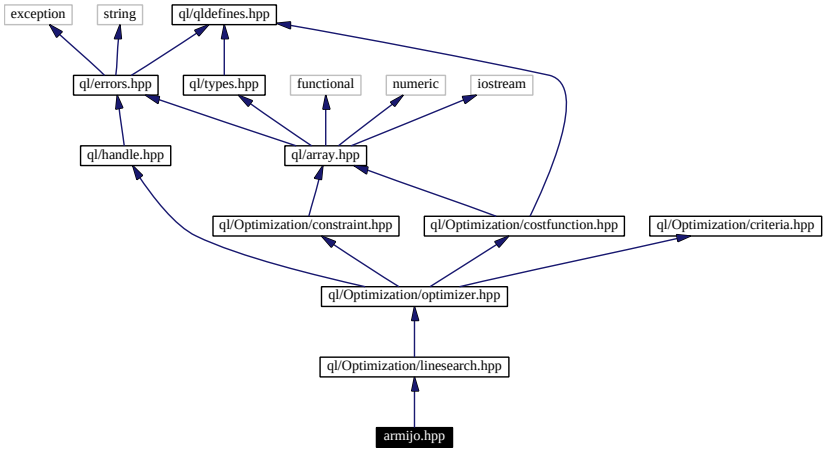
Full path:
ql/Optimization/armijo.cpp

12.14 armijo.hpp File Reference

Armijo line-search class.

`#include "ql/Optimization/linesearch.hpp"`

Include dependency graph for armijo.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.14.1 Detailed Description

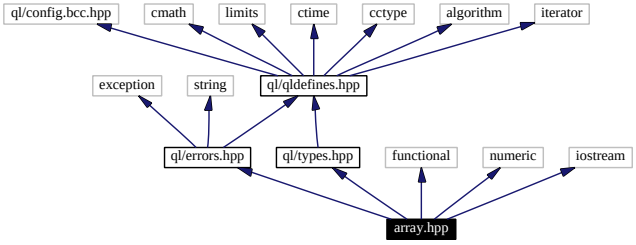
Full path:
ql/Optimization/armijo.hpp

12.15 array.hpp File Reference

1-D array used in linear algebra.

```
#include <ql/types.hpp>
#include <ql/errors.hpp>
#include <functional>
#include <numeric>
#include <iostream>
```

Include dependency graph for array.hpp:



Namespaces

- namespace QuantLib

12.15.1 Detailed Description

Full path:
ql/array.hpp

12.16 audlibor.hpp File Reference

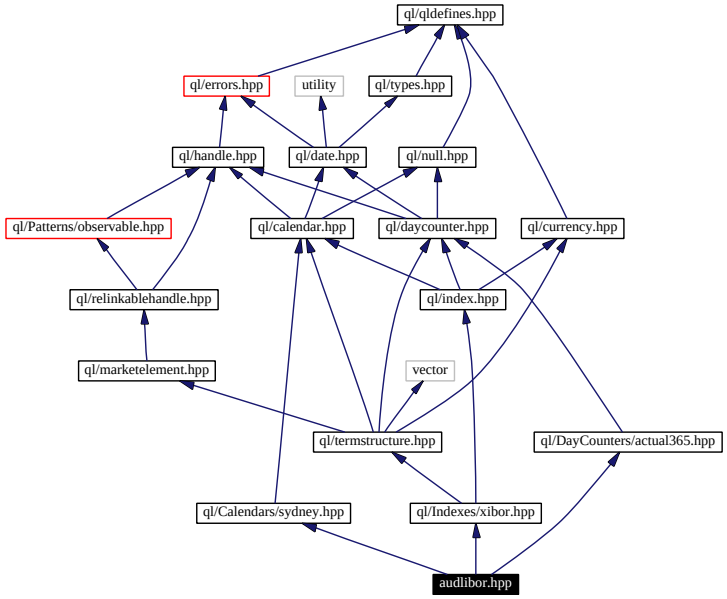
AUD Libor index (check settlement days).

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/sydney.hpp>`

`#include <ql/DayCounters/actual365.hpp>`

Include dependency graph for audlibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.16.1 Detailed Description

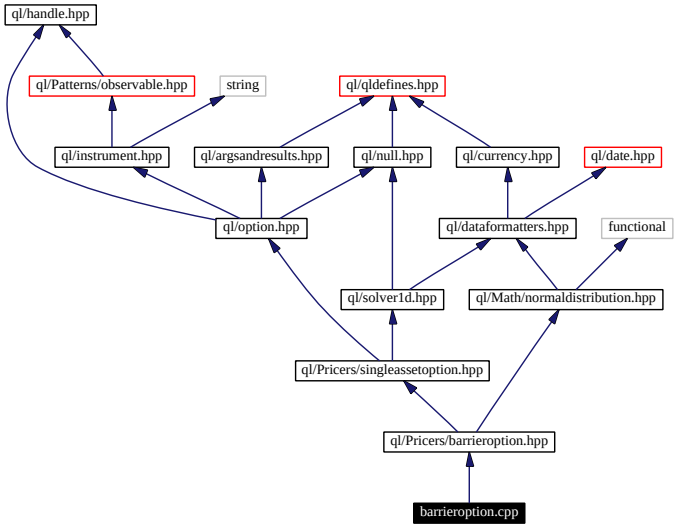
Full path:
ql/Indexes/audlibor.hpp

12.17 barrieroption.cpp File Reference

barrier option.

`#include <ql/Pricers/barrieroption.hpp>`

Include dependency graph for barrieroption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.17.1 Detailed Description

Full path:
ql/Pricers/barrieroption.cpp

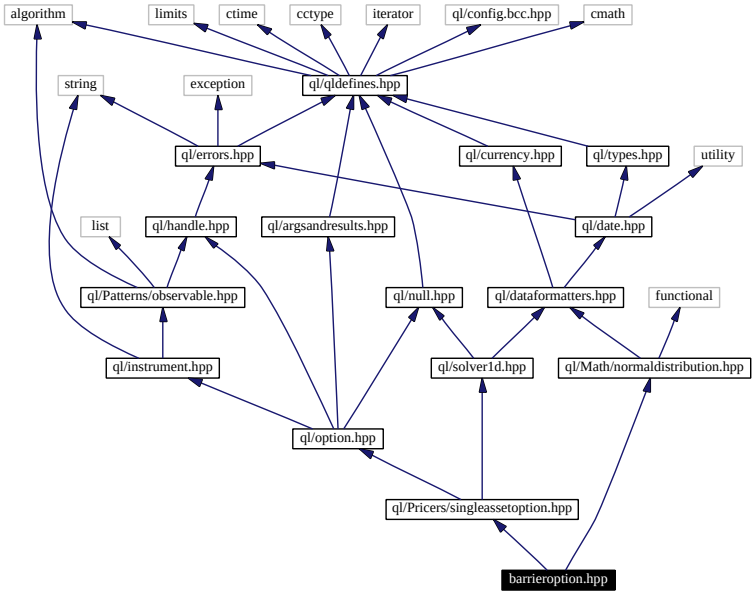
12.18 barrieroption.hpp File Reference

barrier option.

`#include <ql/Pricers/singleassetoption.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

Include dependency graph for barrieroption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

Compounds

- class QuantLib::Pricers::BarrierOption

  Barrier option.

12.18.1 Detailed Description

Full path:

ql/Pricers/barrieroption.hpp

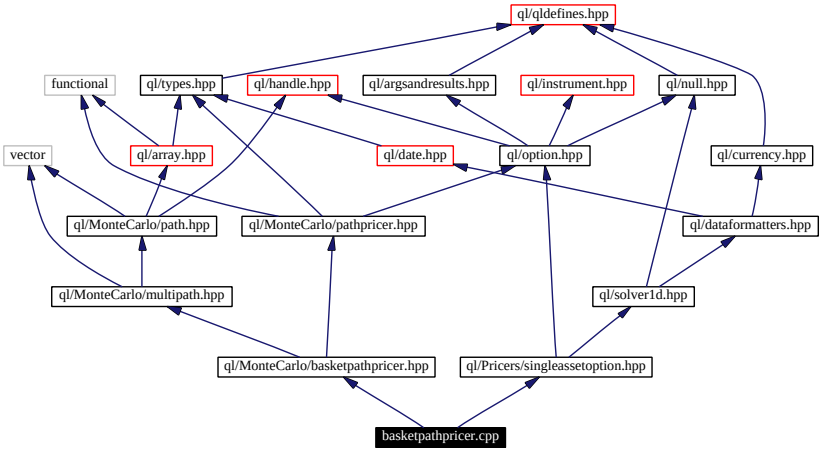
12.19 basketpathpricer.cpp File Reference

multipath pricer for European-type basket option.

`#include <ql/MonteCarlo/basketpathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for basketpathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.19.1 Detailed Description

Full path:

MonteCarlo/basketpathpricer.cpp

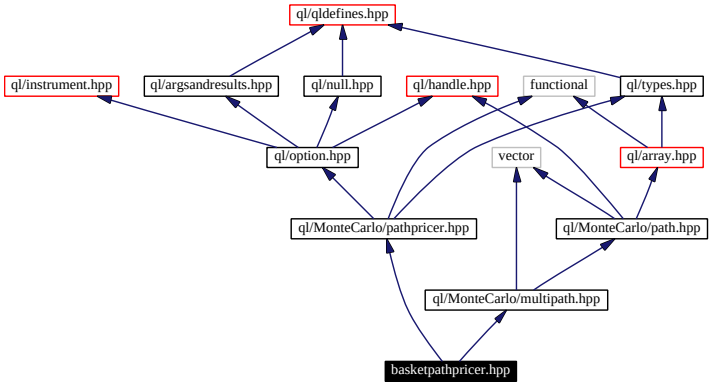
12.20 basketpathpricer.hpp File Reference

multipath pricer for European-type basket option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/multipath.hpp>`

Include dependency graph for basketpathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.20.1 Detailed Description

Full path:
ql/MonteCarlo/basketpathpricer.hpp

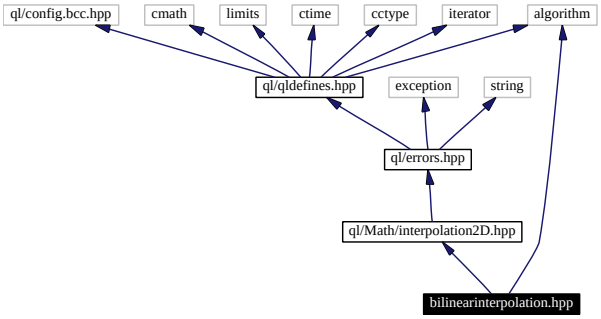
12.21 bilinearinterpolation.hpp File Reference

bilinear interpolation between discrete points.

`#include <ql/Math/interpolation2D.hpp>`

`#include <algorithm>`

Include dependency graph for bilinearinterpolation.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.21.1 Detailed Description

Full path:
ql/Math/bilinearinterpolation.hpp

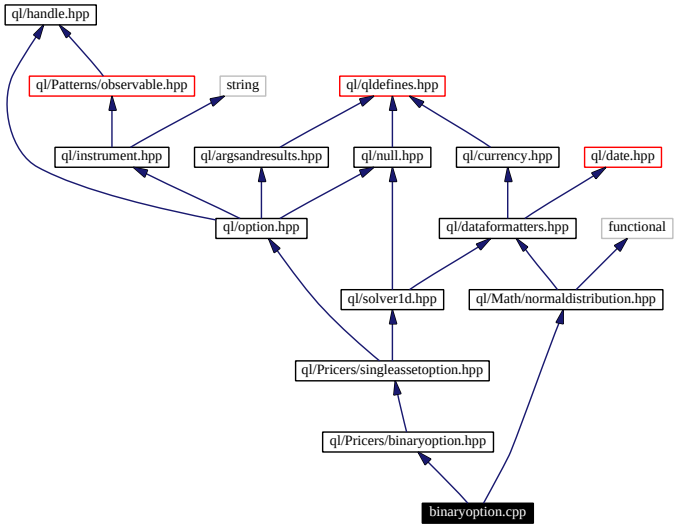
12.22 binaryoption.cpp File Reference

European style cash-or-nothing option.

`#include <ql/Pricers/binaryoption.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

Include dependency graph for binaryoption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.22.1 Detailed Description

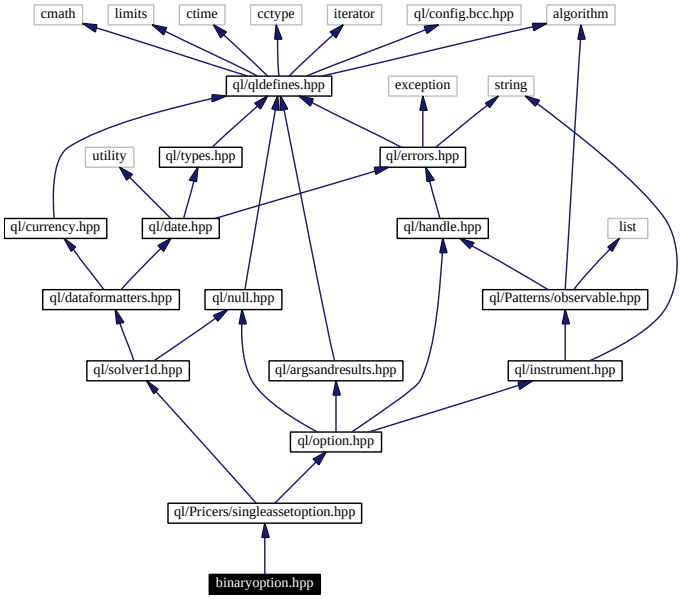
Full path:
ql/Pricers/binaryoption.cpp

12.23 binaryoption.hpp File Reference

European style cash-or-nothing option.

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for binaryoption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.23.1 Detailed Description

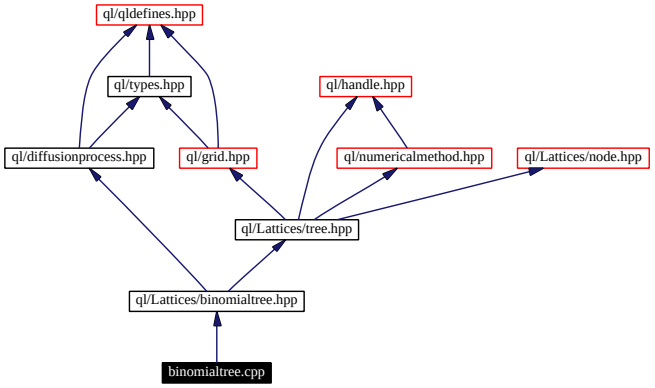
Full path:
ql/Pricers/binaryoption.hpp

12.24 binomialtree.cpp File Reference

Binomial tree class.

`#include "ql/Lattices/binomialtree.hpp"`

Include dependency graph for binomialtree.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.24.1 Detailed Description

Full path:
ql/Lattices/binomialtree.cpp

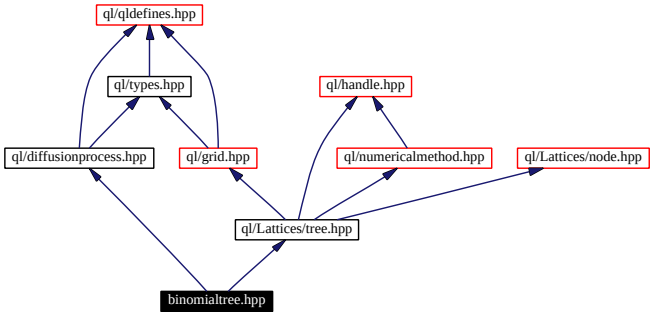
12.25 binomialtree.hpp File Reference

Binomial tree class.

`#include <ql/diffusionprocess.hpp>`

`#include <ql/Lattices/tree.hpp>`

Include dependency graph for binomialtree.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.25.1 Detailed Description

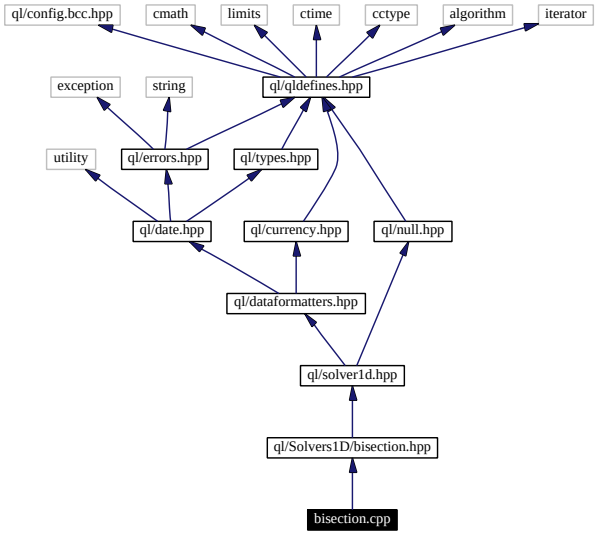
Full path:
ql/Lattices/binomialtree.hpp

12.26 bisection.cpp File Reference

bisection 1-D solver.

`#include <ql/Solvers1D/bisection.hpp>`

Include dependency graph for bisection.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.26.1 Detailed Description

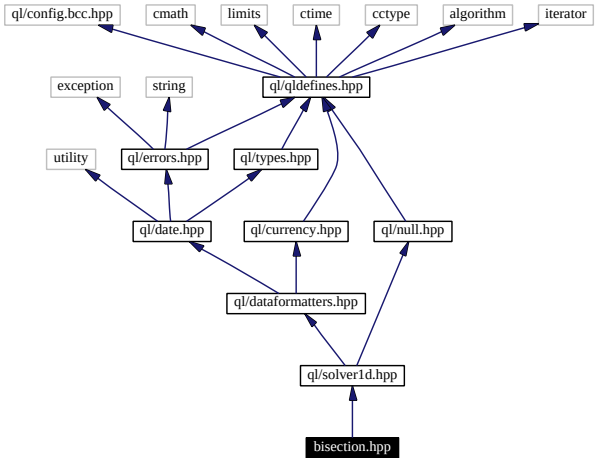
Full path:
ql/Solvers1D/bisection.cpp

12.27 bisection.hpp File Reference

bisection 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for bisection.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.27.1 Detailed Description

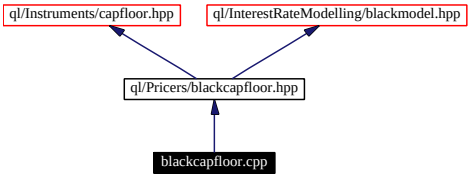
Full path:
ql/Solvers1D/bisection.hpp

12.28 blackcapfloor.cpp File Reference

European capfloor calculated using Black formula.

`#include "ql/Pricers/blackcapfloor.hpp"`

Include dependency graph for blackcapfloor.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.28.1 Detailed Description

Full path:
ql/Pricers/blackcapfloor.cpp

12.29 blackcapfloor.hpp File Reference

CapFloor calculated using the Black formula.

`#include <ql/Instruments/capfloor.hpp>`

`#include <ql/InterestRateModelling/blackmodel.hpp>`

Include dependency graph for blackcapfloor.hpp:

Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.29.1 Detailed Description

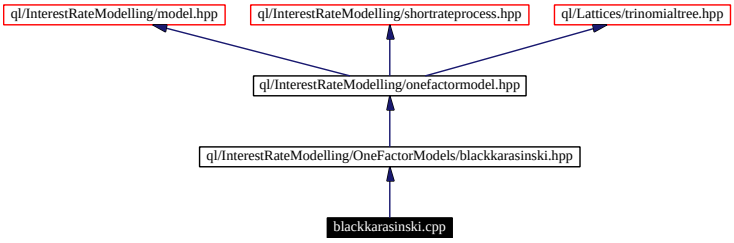
Full path:
ql/Pricers/blackcapfloor.hpp

12.30 blackkarasinski.cpp File Reference

Black-Karasinski model.

`#include "ql/InterestRateModelling/OneFactorModels/blackkarasinski.hpp"`

Include dependency graph for blackkarasinski.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.30.1 Detailed Description

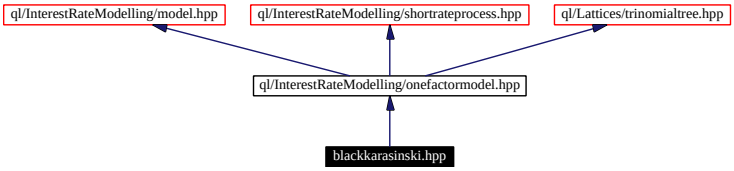
Full path:
ql/InterestRateModelling/OneFactorModels/blackkarasinski.cpp

12.31 blackkarasinski.hpp File Reference

Black-Karasinski model.

`#include <ql/InterestRateModelling/onefactormodel.hpp>`

Include dependency graph for blackkarasinski.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.31.1 Detailed Description

Full path:
ql/InterestRateModelling/OneFactorModels/blackkarasinski.hpp

12.32 blackmodel.hpp File Reference

Abstract class for Black-type models (market models).

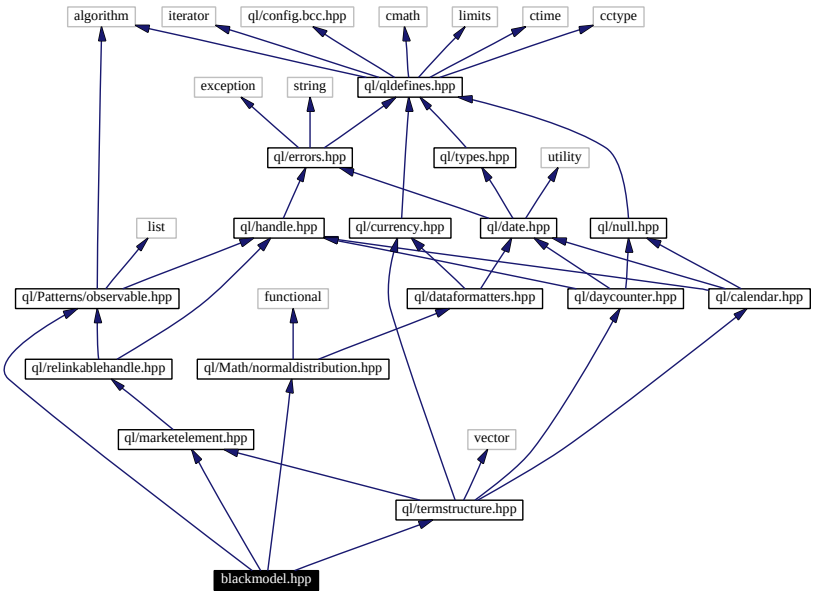
`#include <ql/marketelement.hpp>`

`#include <ql/termstructure.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

`#include <ql/Patterns/observable.hpp>`

Include dependency graph for blackmodel.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.32.1 Detailed Description

Full path:

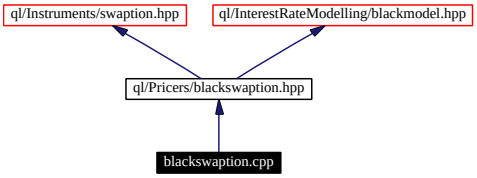
ql/InterestRateModelling/blackmodel.hpp

12.33 blackswaption.cpp File Reference

European swaption calculated using Black formula.

`#include "ql/Pricers/blackswaption.hpp"`

Include dependency graph for blackswaption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.33.1 Detailed Description

Full path:
ql/Pricers/blackswaption.cpp

12.34 blackswaption.hpp File Reference

Swaption calculated using the Black formula.

`#include <ql/Instruments/swaption.hpp>`

`#include <ql/InterestRateModelling/blackmodel.hpp>`

Include dependency graph for blackswaption.hpp:

Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.34.1 Detailed Description

Full path:
ql/Pricers/blackswaption.hpp

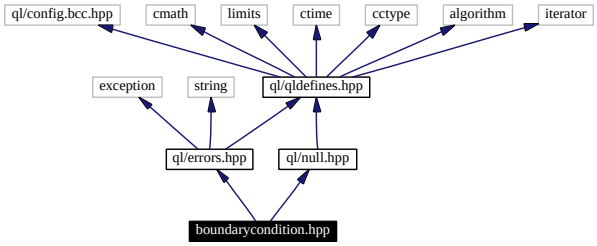
12.35 boundarycondition.hpp File Reference

boundary conditions for differential operators.

`#include <ql/null.hpp>`

`#include <ql/errors.hpp>`

Include dependency graph for boundarycondition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.35.1 Detailed Description

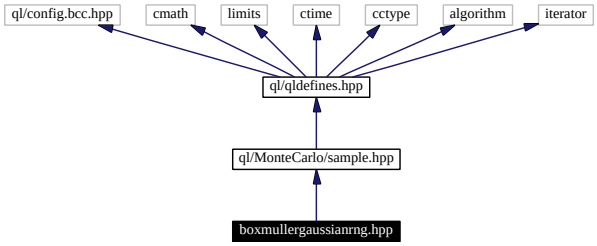
Full path:
ql/FiniteDifferences/boundarycondition.hpp

12.36 boxmullergaussianrng.hpp File Reference

Box-Muller Gaussian random-number generator.

`#include <ql/MonteCarlo/sample.hpp>`

Include dependency graph for boxmullergaussianrng.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.36.1 Detailed Description

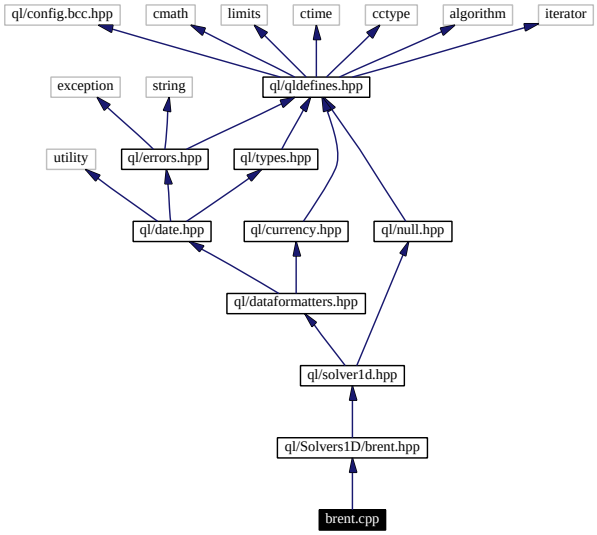
Full path:
ql/RandomNumbers/boxmullergaussianrng.hpp

12.37 brent.cpp File Reference

Brent 1-D solver.

`#include <ql/Solvers1D/brent.hpp>`

Include dependency graph for brent.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

Defines

- #define **SIGN**(a, b) ((b) >= 0.0 ? QL_FABS(a) : -QL_FABS(a))

12.37.1 Detailed Description

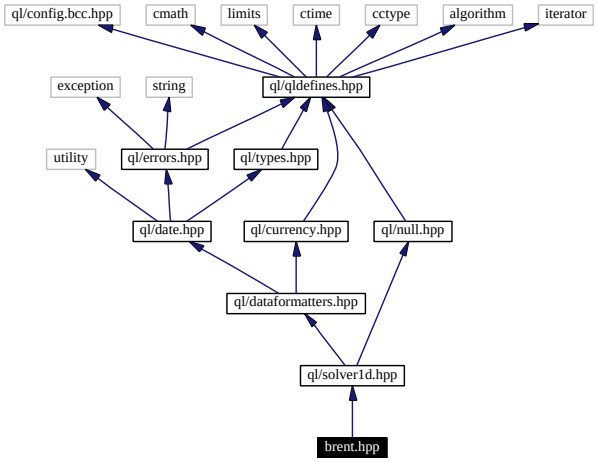
Full path:
ql/Solvers1D/brent.cpp

12.38 brent.hpp File Reference

Brent 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for brent.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.38.1 Detailed Description

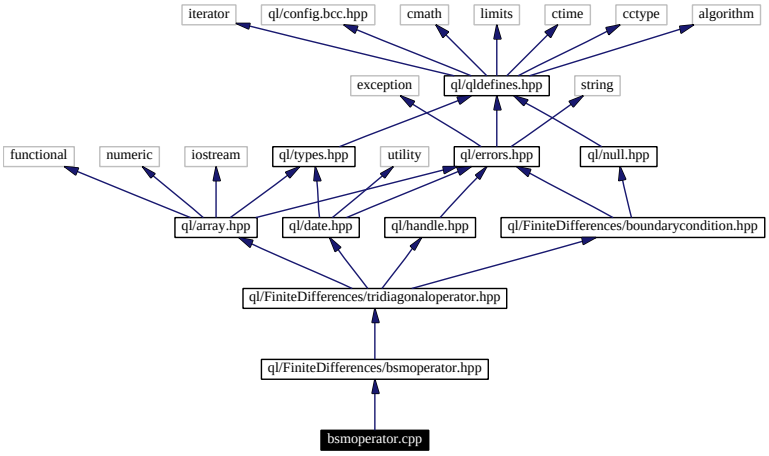
Full path:
ql/Solvers1D/brent.hpp

12.39 bsmoperator.cpp File Reference

differential operator for Black-Scholes-Merton equation.

`#include <ql/FiniteDifferences/bsmoperator.hpp>`

Include dependency graph for bsmoperator.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.39.1 Detailed Description

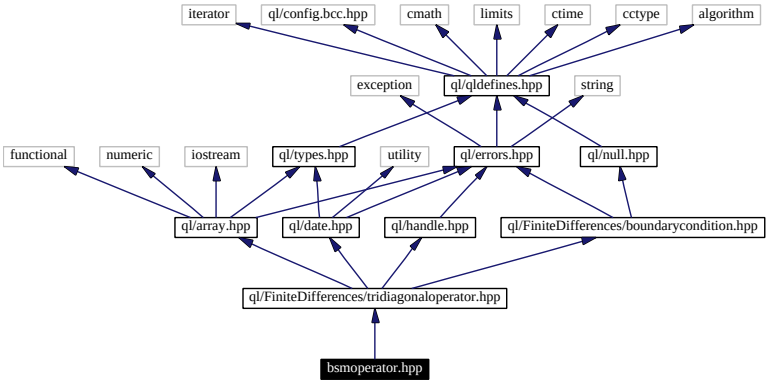
Full path:
FiniteDifferences/bsmoperator.cpp

12.40 bsmoperator.hpp File Reference

differential operator for Black-Scholes-Merton equation.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for bsmoperator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.40.1 Detailed Description

Full path:
ql/FiniteDifferences/bsmoperator.hpp

12.41 cadlibor.hpp File Reference

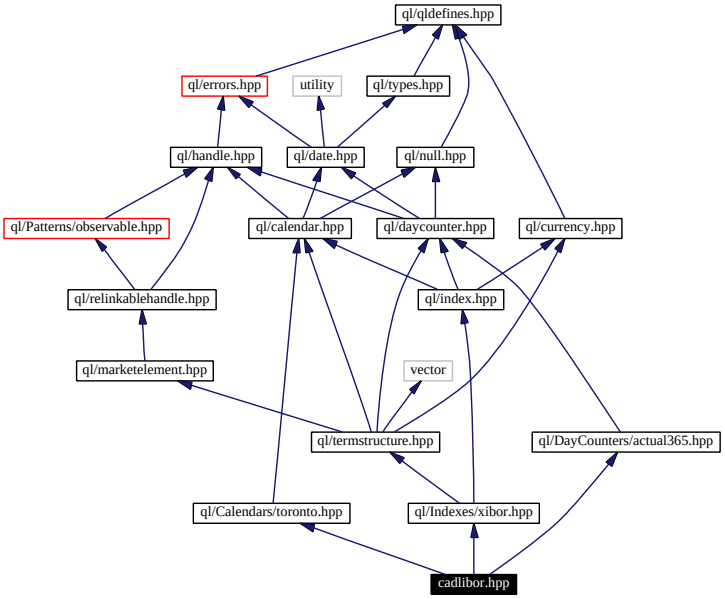
CAD Libor index (Also known as CDOR, check settlement days).

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/toronto.hpp>`

`#include <ql/DayCounters/actual365.hpp>`

Include dependency graph for cadlibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.41.1 Detailed Description

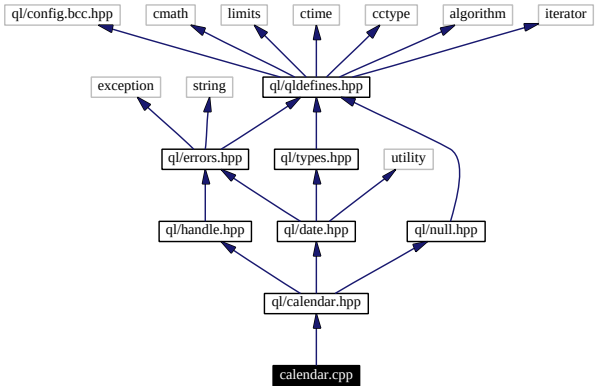
Full path:
ql/Indexes/cadlibor.hpp

12.42 calendar.cpp File Reference

Abstract calendar class.

`#include <ql/calendar.hpp>`

Include dependency graph for calendar.cpp:



Namespaces

- namespace QuantLib

12.42.1 Detailed Description

Full path:
ql/calendar.cpp

12.43 calendar.hpp File Reference

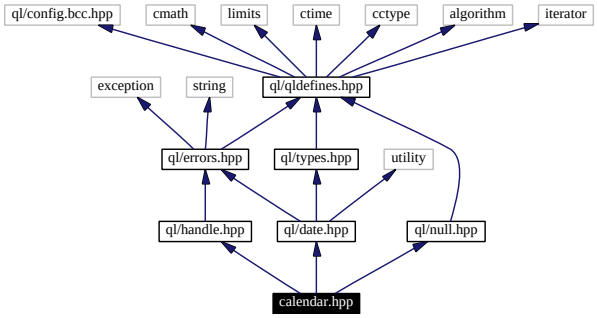
calendar class.

`#include <ql/date.hpp>`

`#include <ql/handle.hpp>`

`#include <ql/null.hpp>`

Include dependency graph for calendar.hpp:



Namespaces

- namespace QuantLib::Calendars
- namespace QuantLib

12.43.1 Detailed Description

Full path:
ql/calendar.hpp

12.44 calibrationhelper.cpp File Reference

Calibration helper class.

```
#include "ql/InterestRateModelling/calibrationhelper.hpp"
#include "ql/Solvers1D/brent.hpp"
```

Include dependency graph for calibrationhelper.cpp:

Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.44.1 Detailed Description

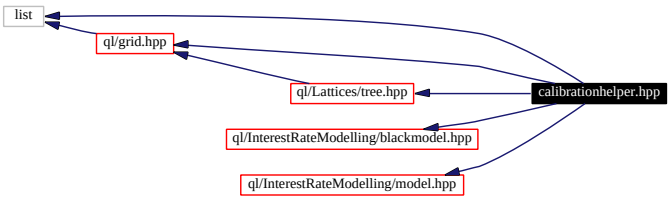
Full path:
ql/InterestRateModelling/CalibrationHelpers/calibrationhelper.hpp

12.45 calibrationhelper.hpp File Reference

Calibration helper class.

```
#include <ql/grid.hpp>
#include <ql/InterestRateModelling/blackmodel.hpp>
#include <ql/InterestRateModelling/model.hpp>
#include <ql/Lattices/tree.hpp>
#include <list>
```

Include dependency graph for calibrationhelper.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.45.1 Detailed Description

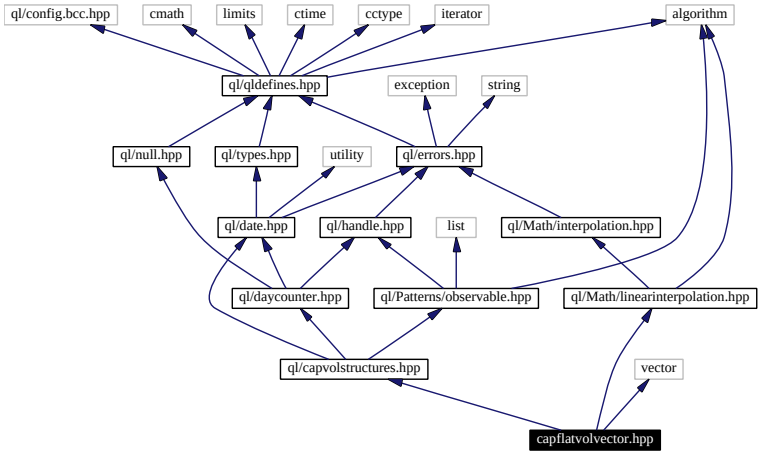
Full path:
ql/InterestRateModelling/calibrationhelper.hpp

12.46 capflatvolvector.hpp File Reference

Cap/floor at-the-money flat volatility vector.

```
#include "ql/capvolstructures.hpp"
#include "ql/Math/linearinterpolation.hpp"
#include <vector>
```

Include dependency graph for capflatvolvector.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Volatilities**

12.46.1 Detailed Description

Full path:
ql/Volatilities/capflatvolmatrix.hpp

12.47 capfloor.cpp File Reference

European cap and floor class.

```
#include "ql/Instruments/capfloor.hpp"
#include "ql/CashFlows/floatingratecoupon.hpp"
```

Include dependency graph for capfloor.cpp:

Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.47.1 Detailed Description

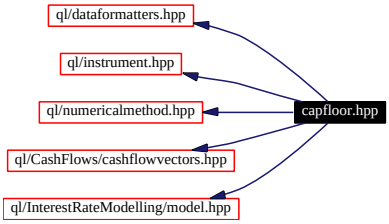
Full path:
ql/Instruments/capfloor.cpp

12.48 capfloor.hpp File Reference

Cap and Floor class.

```
#include "ql/dataformatters.hpp"
#include <ql/instrument.hpp>
#include <ql/numericalmethod.hpp>
#include <ql/CashFlows/cashflowvectors.hpp>
#include <ql/InterestRateModelling/model.hpp>
```

Include dependency graph for capfloor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments
- namespace QuantLib::Pricers

12.48.1 Detailed Description

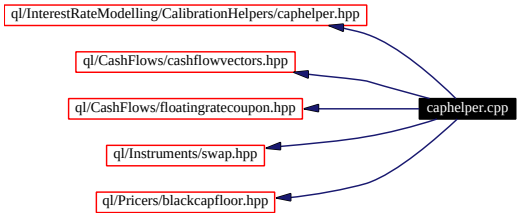
Full path:
ql/Instruments/capfloor.hpp

12.49 caphelper.cpp File Reference

Cap calibration helper.

```
#include "ql/InterestRateModelling/CalibrationHelpers/caphelper.hpp"
#include "ql/CashFlows/cashflowvectors.hpp"
#include "ql/CashFlows/floatingratecoupon.hpp"
#include "ql/Instruments/swap.hpp"
#include "ql/Pricers/blackcapfloor.hpp"
```

Include dependency graph for caphelper.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**
- namespace **QuantLib::InterestRateModelling::CalibrationHelpers**

12.49.1 Detailed Description

Full path:
ql/InterestRateModelling/CalibrationHelpers/caphelper.hpp

12.50 caphelper.hpp File Reference

CapHelper calibration helper.

```
#include "ql/InterestRateModelling/calibrationhelper.hpp"
#include "ql/Instruments/capfloor.hpp"
```

Include dependency graph for caphelper.hpp:

Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**
- namespace **QuantLib::InterestRateModelling::CalibrationHelpers**

12.50.1 Detailed Description

Full path:
ql/InterestRateModelling/CalibrationHelpers/caphelper.hpp

12.51 capvolstructures.hpp File Reference

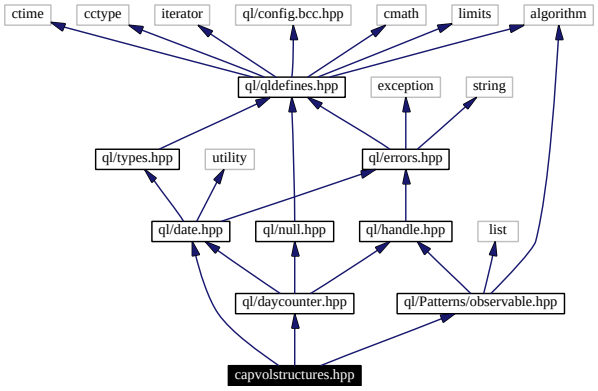
Cap/Floor volatility structures.

`#include <ql/date.hpp>`

`#include <ql/daycounter.hpp>`

`#include <ql/Patterns/observable.hpp>`

Include dependency graph for capvolstructures.hpp:



Namespaces

- namespace QuantLib

12.51.1 Detailed Description

Full path:
ql/capvolstructures.hpp

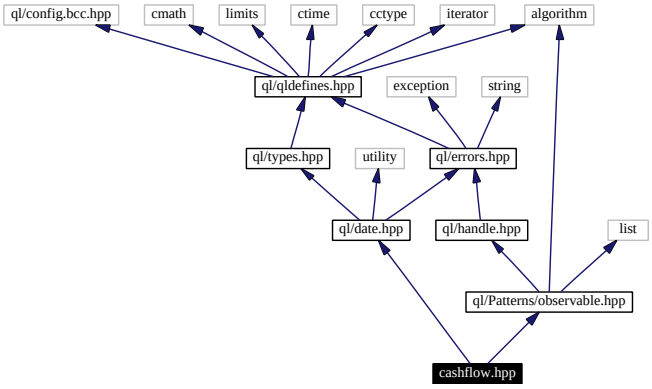
12.52 cashflow.hpp File Reference

Base class for cash flows.

`#include <ql/date.hpp>`

`#include <ql/Patterns/observable.hpp>`

Include dependency graph for cashflow.hpp:



Namespaces

- namespace QuantLib::CashFlows
- namespace QuantLib

12.52.1 Detailed Description

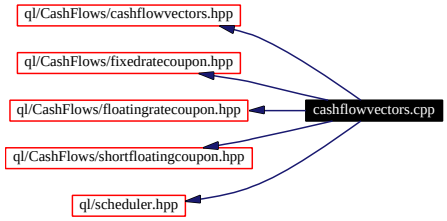
Full path:
ql/cashflow.hpp

12.53 cashflowvectors.cpp File Reference

Cash flow vector builders.

```
#include <ql/CashFlows/cashflowvectors.hpp>
#include <ql/CashFlows/fixedratecoupon.hpp>
#include <ql/CashFlows/floatingratecoupon.hpp>
#include <ql/CashFlows/shortfloatingcoupon.hpp>
#include <ql/scheduler.hpp>
```

Include dependency graph for cashflowvectors.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.53.1 Detailed Description

Full path:
ql/CashFlows/cashflowvectors.cpp

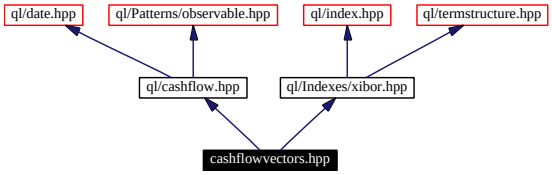
12.54 cashflowvectors.hpp File Reference

Cash flow vector builders.

`#include <ql/cashflow.hpp>`

`#include <ql/Indexes/xibor.hpp>`

Include dependency graph for cashflowvectors.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.54.1 Detailed Description

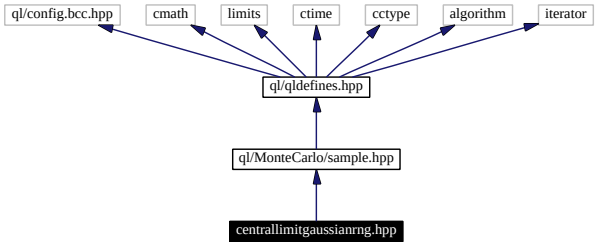
Full path:
ql/CashFlows/cashflowvectors.hpp

12.55 centrallimitgaussianrng.hpp File Reference

Central limit Gaussian random-number generator.

`#include <ql/MonteCarlo/sample.hpp>`

Include dependency graph for centrallimitgaussianrng.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.55.1 Detailed Description

Full path:
ql/RandomNumbers/centrallimitgaussianrng.hpp

12.56 chflibor.hpp File Reference

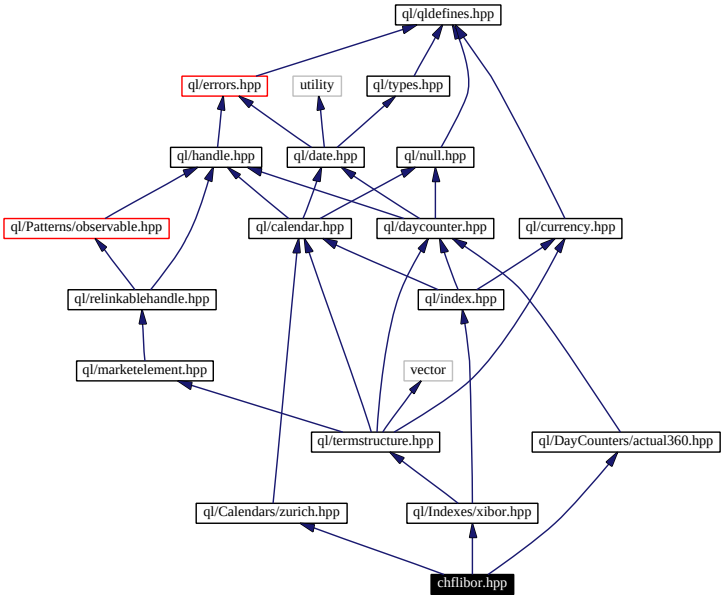
CHF Libor index (Also known as ZIBOR, check settlement days and day-count).

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/zurich.hpp>`

`#include <ql/DayCounters/actual360.hpp>`

Include dependency graph for chflibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.56.1 Detailed Description

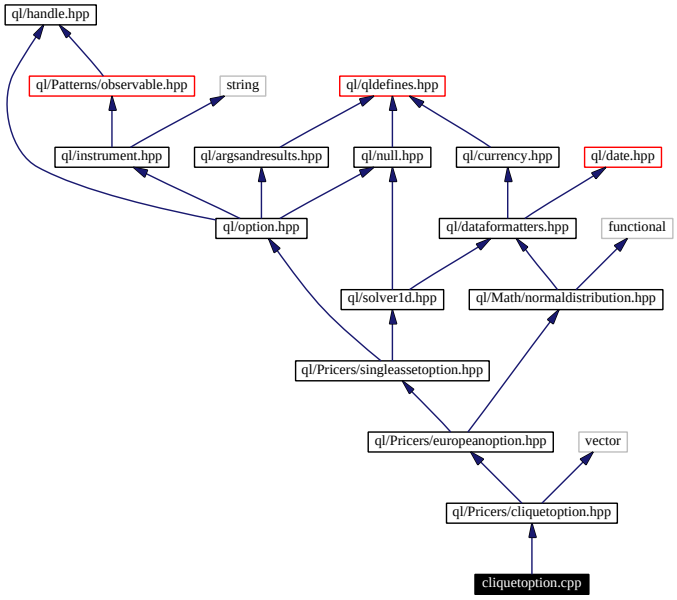
Full path:
ql/Indexes/chflibor.hpp

12.57 cliquetoption.cpp File Reference

Textbook example of european-style multi-period option.

`#include <ql/Pricers/cliquetoption.hpp>`

Include dependency graph for cliquetoption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.57.1 Detailed Description

Full path:
ql/Pricers/cliquetoption.cpp

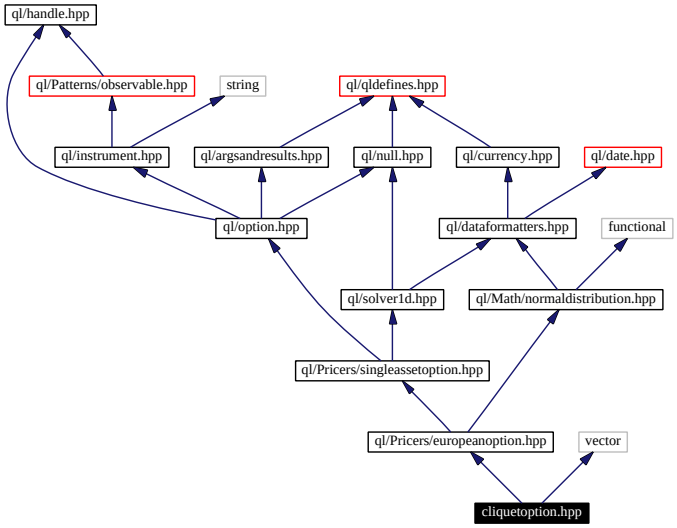
12.58 cliquetoption.hpp File Reference

Textbook example of european-style multi-period option.

`#include <ql/Pricers/europeanoption.hpp>`

`#include <vector>`

Include dependency graph for cliquetoption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.58.1 Detailed Description

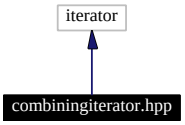
Full path:
ql/Pricers/cliquetoption.hpp

12.59 combiningiterator.hpp File Reference

Iterator mapping a function to a set of underlying sequences.

`#include <iterator>`

Include dependency graph for combiningiterator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.59.1 Detailed Description

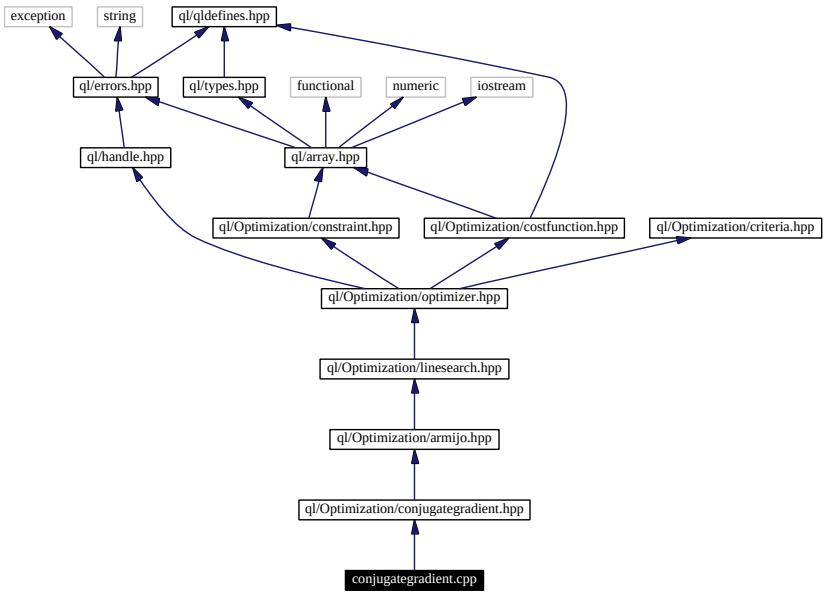
Full path:
ql/Utilities/combiningiterator.hpp

12.60 conjugategradient.cpp File Reference

Conjugate gradient optimization method.

`#include "ql/Optimization/conjugategradient.hpp"`

Include dependency graph for conjugategradient.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.60.1 Detailed Description

Full path:

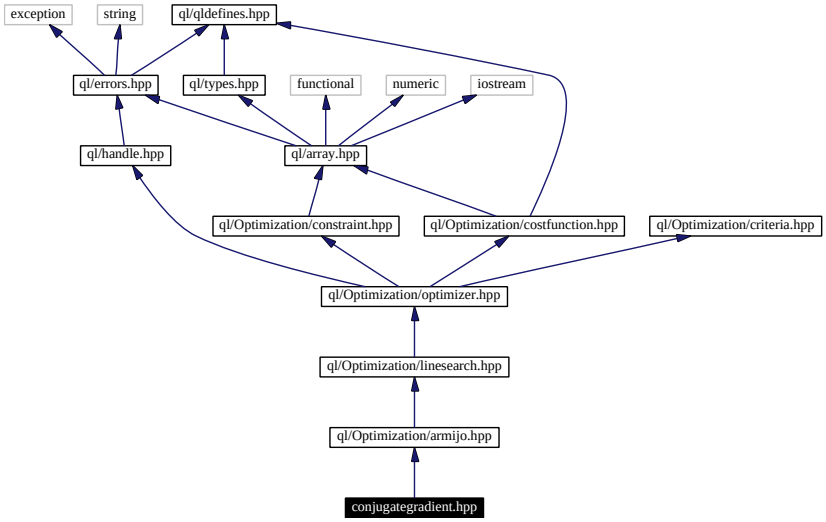
ql/Optimization/conjugategradient.cpp

12.61 conjugategradient.hpp File Reference

Conjugate gradient optimization method.

`#include "ql/Optimization/armijo.hpp"`

Include dependency graph for conjugategradient.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.61.1 Detailed Description

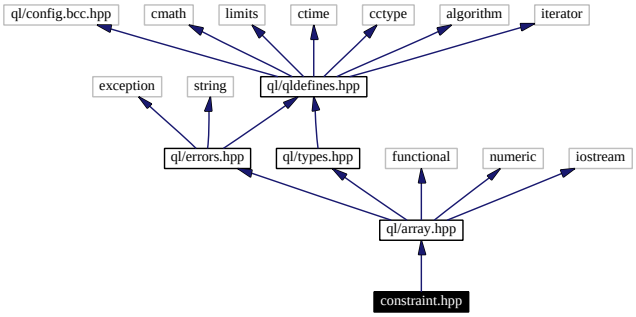
Full path:
ql/Optimization/conjugategradient.hpp

12.62 constraint.hpp File Reference

Abstract constraint class.

`#include "ql/array.hpp"`

Include dependency graph for constraint.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.62.1 Detailed Description

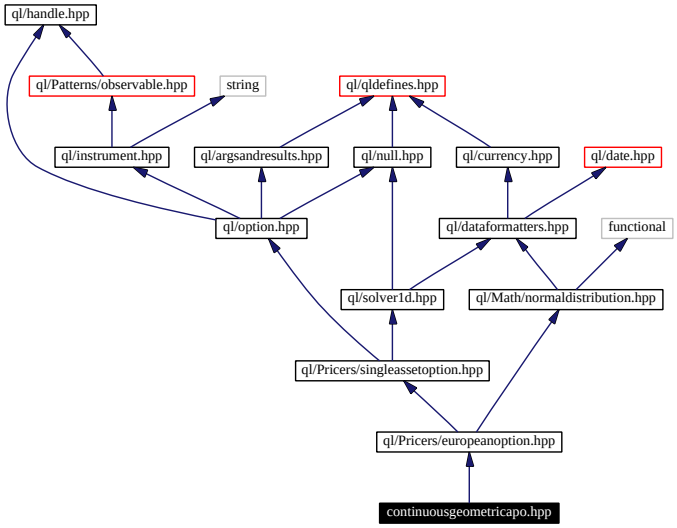
Full path:
ql/Optimization/constraint.hpp

12.63 continuousgeometricapo.hpp File Reference

Continuous Geometric Average Price Option (European exercise).

`#include <ql/Pricers/europeanoption.hpp>`

Include dependency graph for continuousgeometricapo.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.63.1 Detailed Description

Full path:
ql/Pricers/continuousgeometricapo.hpp

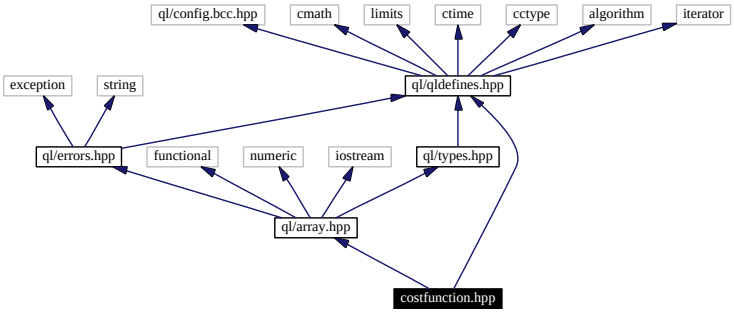
12.64 costfunction.hpp File Reference

Optimization cost function class.

`#include <ql/qldefines.hpp>`

`#include <ql/array.hpp>`

Include dependency graph for costfunction.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.64.1 Detailed Description

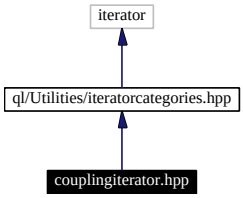
Full path:
ql/Optimization/costfunction.hpp

12.65 couplingiterator.hpp File Reference

Iterator mapping a function to a pair of underlying sequences.

`#include <ql/Utilities/iteratorcategories.hpp>`

Include dependency graph for couplingiterator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.65.1 Detailed Description

Full path:
ql/Utilities/couplingiterator.hpp

12.66 coupon.hpp File Reference

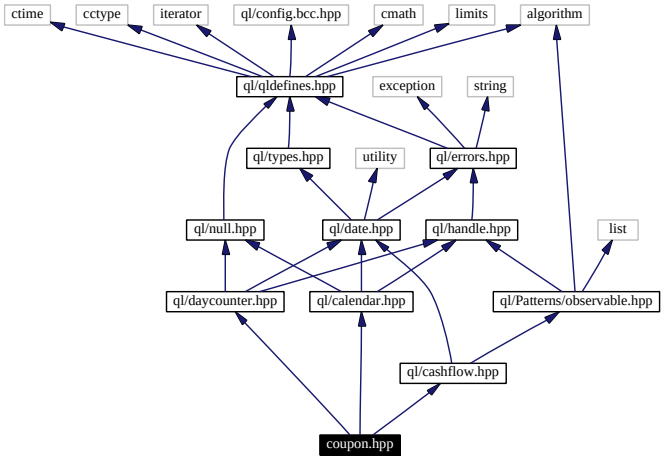
Coupon accruing over a fixed period.

`#include <ql/cashflow.hpp>`

`#include <ql/calendar.hpp>`

`#include <ql/daycounter.hpp>`

Include dependency graph for coupon.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.66.1 Detailed Description

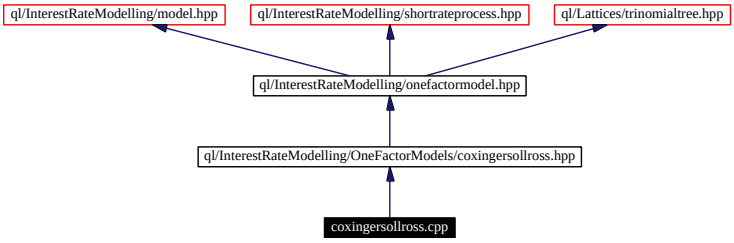
Full path:
ql/CashFlows/coupon.hpp

12.67 coxingersollross.cpp File Reference

Cox-Ingersoll-Ross model.

`#include "ql/InterestRateModelling/OneFactorModels/coxingersollross.hpp"`

Include dependency graph for coxingersollross.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.67.1 Detailed Description

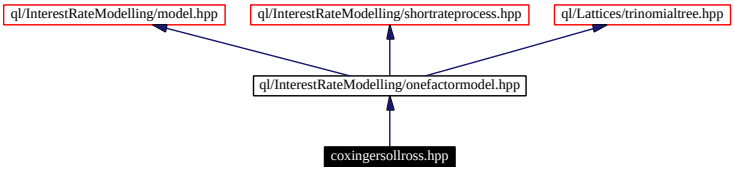
Full path:
ql/InterestRateModelling/OneFactorModels/coxingersollross.cpp

12.68 coxingersollross.hpp File Reference

Cox-Ingersoll-Ross model.

`#include "ql/InterestRateModelling/onefactormodel.hpp"`

Include dependency graph for coxingersollross.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.68.1 Detailed Description

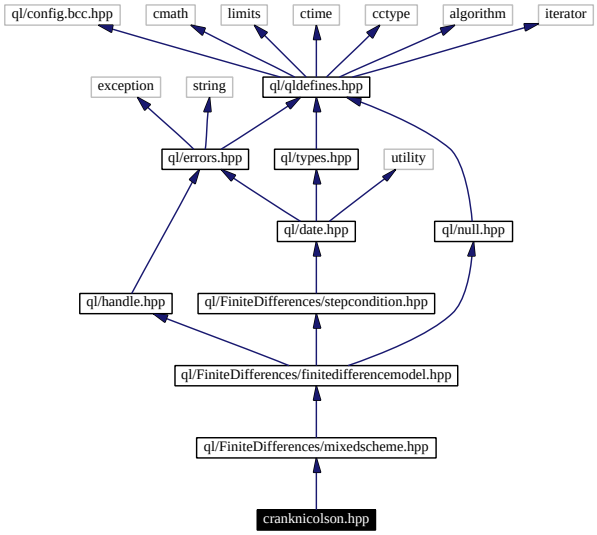
Full path:
ql/InterestRateModelling/OneFactorModels/coxingersollross.hpp

12.69 cranknicolson.hpp File Reference

Crank-Nicolson scheme for finite difference methods.

`#include <ql/FiniteDifferences/mixedscheme.hpp>`

Include dependency graph for cranknicolson.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.69.1 Detailed Description

Full path:
ql/FiniteDifferences/cranknicolson.hpp

12.70 criteria.hpp File Reference

Optimization criteria class.

Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.70.1 Detailed Description

Full path:
ql/Optimization/criteria.hpp

12.71 cubicspline.hpp File Reference

cubic spline interpolation between discrete points.

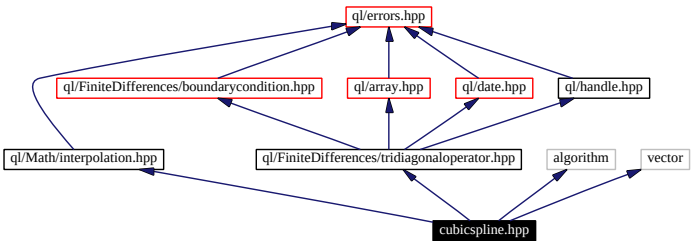
`#include <ql/Math/interpolation.hpp>`

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

`#include <algorithm>`

`#include <vector>`

Include dependency graph for cubicspline.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.71.1 Detailed Description

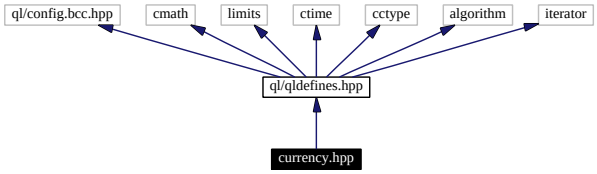
Full path:
ql/Math/cubicspline.hpp

12.72 currency.hpp File Reference

Known currencies.

`#include <ql/qldefines.hpp>`

Include dependency graph for currency.hpp:



Namespaces

- namespace QuantLib

12.72.1 Detailed Description

Full path:
ql/currency.hpp

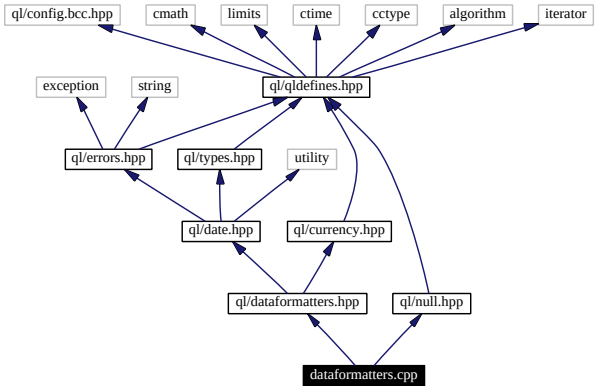
12.73 dataformatters.cpp File Reference

classes used to format data for output.

`#include <ql/dataformatters.hpp>`

`#include <ql/null.hpp>`

Include dependency graph for dataformatters.cpp:



Namespaces

- namespace QuantLib

12.73.1 Detailed Description

Full path:
ql/dataformatters.cpp

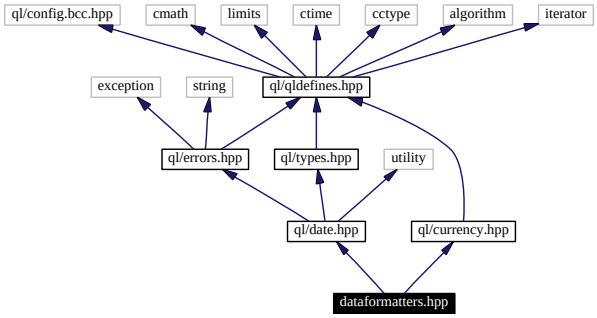
12.74 dataformatters.hpp File Reference

Classes used to format data for output.

`#include <ql/date.hpp>`

`#include <ql/currency.hpp>`

Include dependency graph for dataformatters.hpp:



Namespaces

- namespace QuantLib

12.74.1 Detailed Description

Full path:
ql/dataformatters.hpp

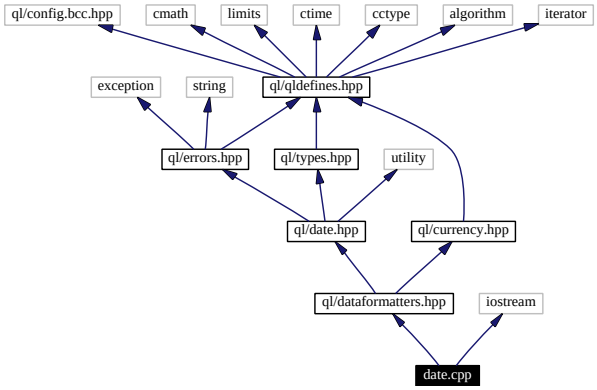
12.75 date.cpp File Reference

date- and time-related classes, typedefs and enumerations.

`#include <ql/dataformatters.hpp>`

`#include <iostream>`

Include dependency graph for date.cpp:



Namespaces

- namespace QuantLib

12.75.1 Detailed Description

Full path:
ql/date.cpp

12.76 date.hpp File Reference

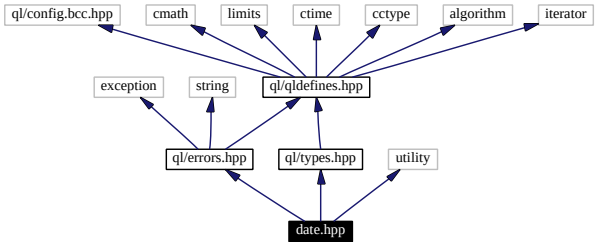
date- and time-related classes, typedefs and enumerations.

`#include <ql/errors.hpp>`

`#include <ql/types.hpp>`

`#include <utility>`

Include dependency graph for date.hpp:



Namespaces

- namespace QuantLib

12.76.1 Detailed Description

Full path:
ql/date.hpp

12.77 daycounter.hpp File Reference

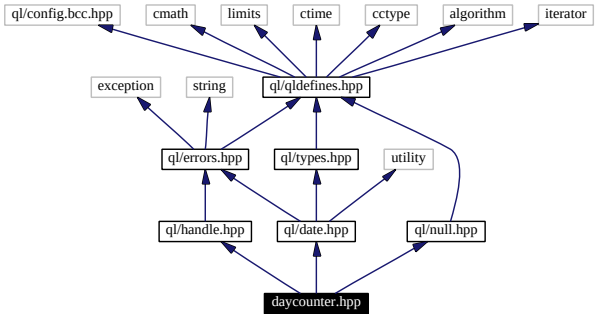
day counter class.

`#include <ql/date.hpp>`

`#include <ql/handle.hpp>`

`#include <ql/null.hpp>`

Include dependency graph for daycounter.hpp:



Namespaces

- namespace QuantLib::DayCounters
- namespace QuantLib

12.77.1 Detailed Description

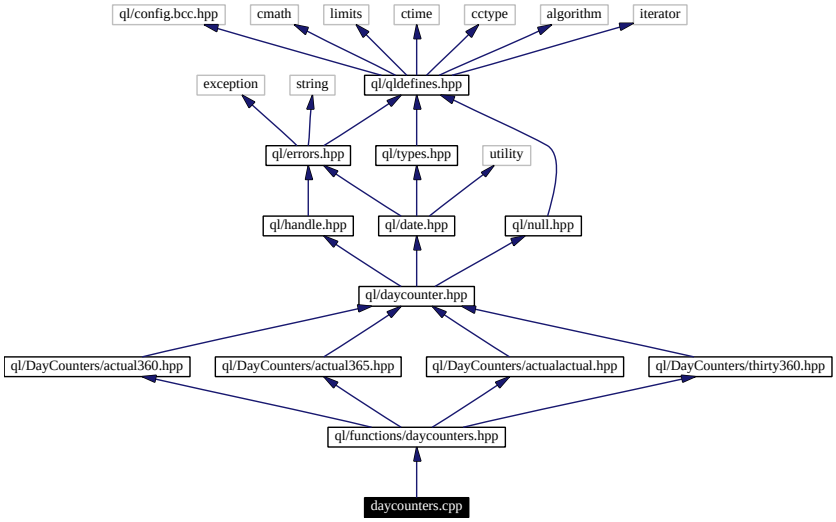
Full path:
ql/daycounter.hpp

12.78 daycounters.cpp File Reference

day counters functions.

`#include <ql/functions/daycounters.hpp>`

Include dependency graph for daycounters.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Functions**

12.78.1 Detailed Description

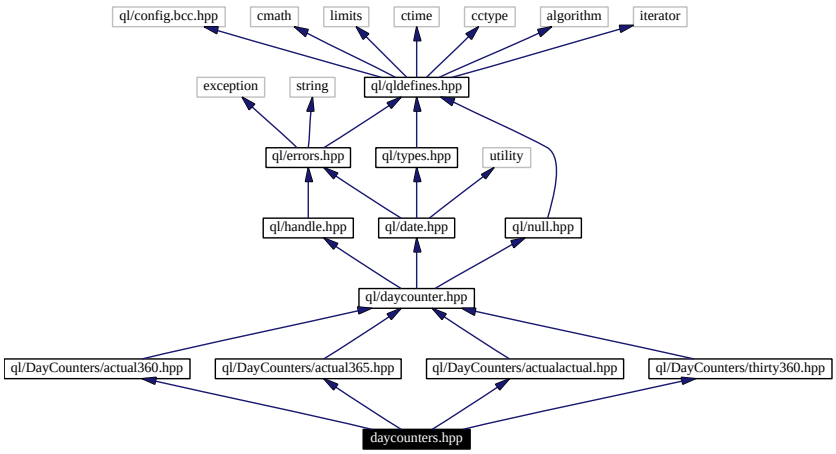
Full path:
ql/functions/daycounters.cpp

12.79 daycounters.hpp File Reference

day counters functions.

```
#include <ql/DayCounters/actual360.hpp>
#include <ql/DayCounters/actual365.hpp>
#include <ql/DayCounters/actualactual.hpp>
#include <ql/DayCounters/thirty360.hpp>
```

Include dependency graph for daycounters.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Functions**

12.79.1 Detailed Description

Full path:
ql/functions/daycounters.hpp

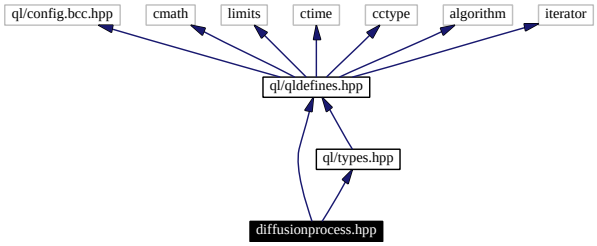
12.80 diffusionprocess.hpp File Reference

Diffusion process.

`#include <ql/qldefines.hpp>`

`#include <ql/types.hpp>`

Include dependency graph for diffusionprocess.hpp:



Namespaces

- namespace QuantLib

12.80.1 Detailed Description

Full path:
ql/diffusionprocess.hpp

12.81 discretegeometricapo.cpp File Reference

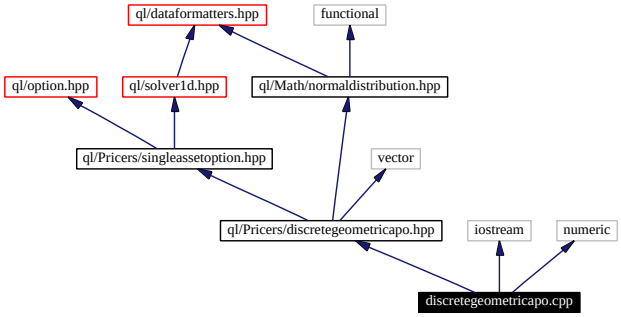
Discrete Geometric Average Price Option.

`#include <ql/Pricers/discretegeometricapo.hpp>`

`#include <iostream>`

`#include <numeric>`

Include dependency graph for discretegeometricapo.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.81.1 Detailed Description

Full path:
ql/Pricers/discretegeometricapo.cpp

12.82 discretegeometricapo.hpp File Reference

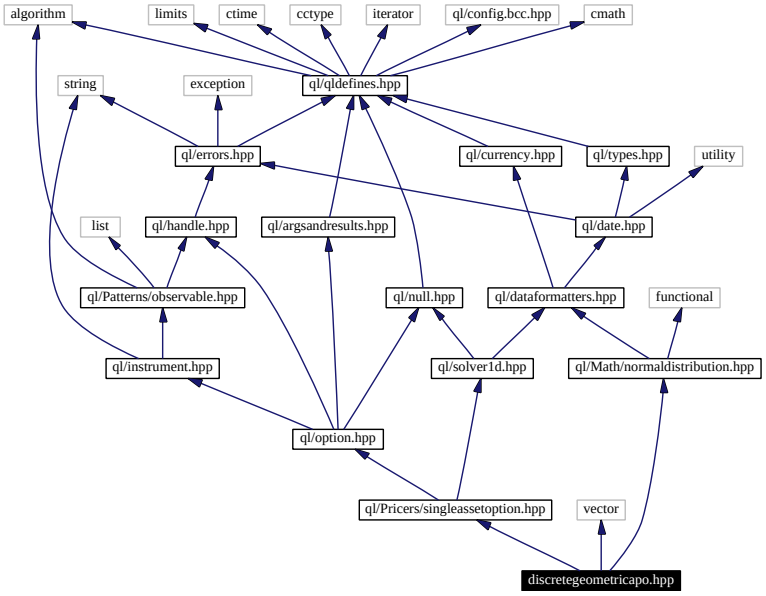
Discrete Geometric Average Price Option.

`#include <ql/Pricers/singleassetoption.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

`#include <vector>`

Include dependency graph for discretegeometricapo.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.82.1 Detailed Description

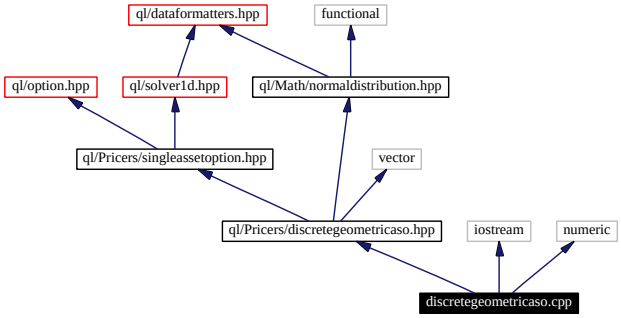
Full path:
ql/Pricers/discretegeometricapo.hpp

12.83 discretegeometricaso.cpp File Reference

Discrete Geometric Average Strike Option.

```
#include <ql/Pricers/discretegeometricaso.hpp>
#include <iostream>
#include <numeric>
```

Include dependency graph for discretegeometricaso.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.83.1 Detailed Description

Full path:
ql/Pricers/discretegeometricaso.cpp

12.84 discretegeometricaso.hpp File Reference

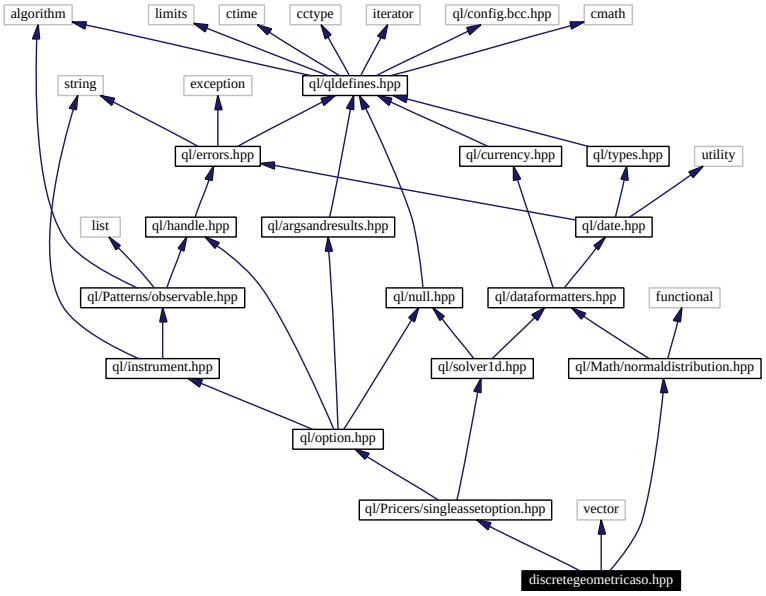
Discrete Geometric Average Strike Option.

`#include <ql/Pricers/singleassetoption.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

`#include <vector>`

Include dependency graph for discretegeometricaso.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.84.1 Detailed Description

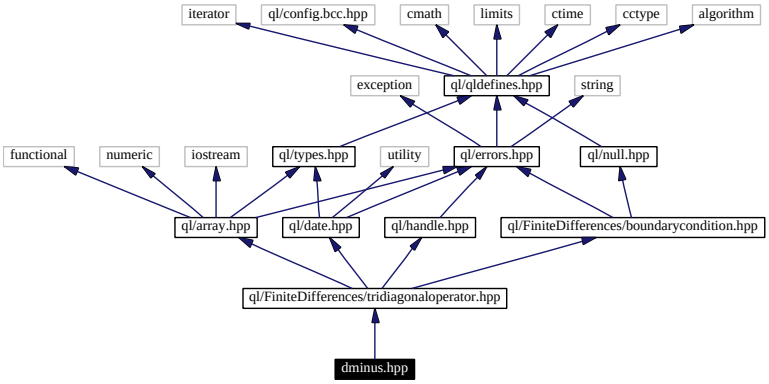
Full path:
ql/Pricers/discretegeometricaso.hpp

12.85 dminus.hpp File Reference

D_- matricial representation.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for dminus.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.85.1 Detailed Description

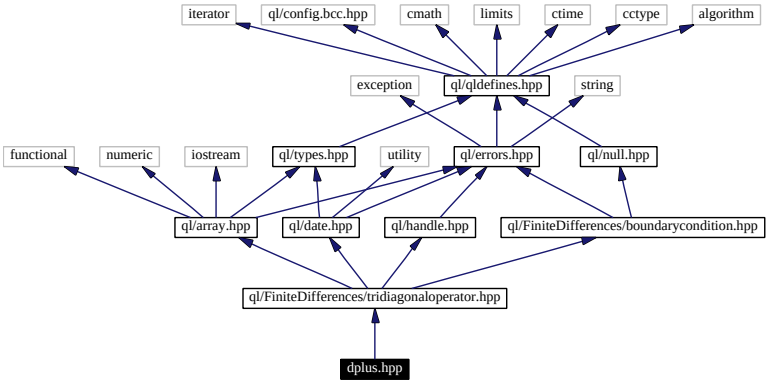
Full path:
ql/FiniteDifferences/dminus.hpp

12.86 dplus.hpp File Reference

D_+ matricial representation.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for dplus.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.86.1 Detailed Description

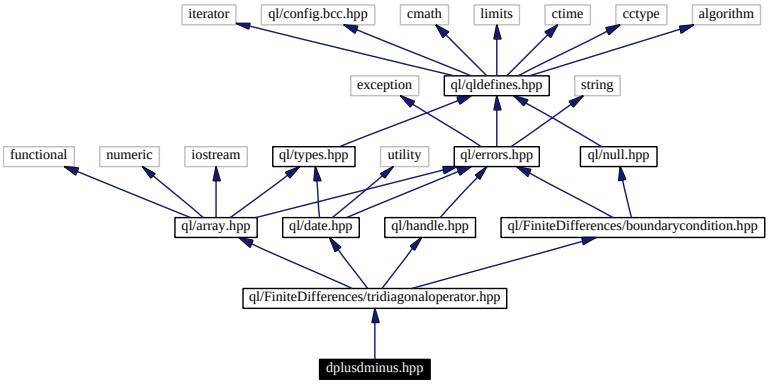
Full path:
ql/FiniteDifferences/dplus.hpp

12.87 dplusdminus.hpp File Reference

D_+D_- matricial representation.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for dplusdminus.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.87.1 Detailed Description

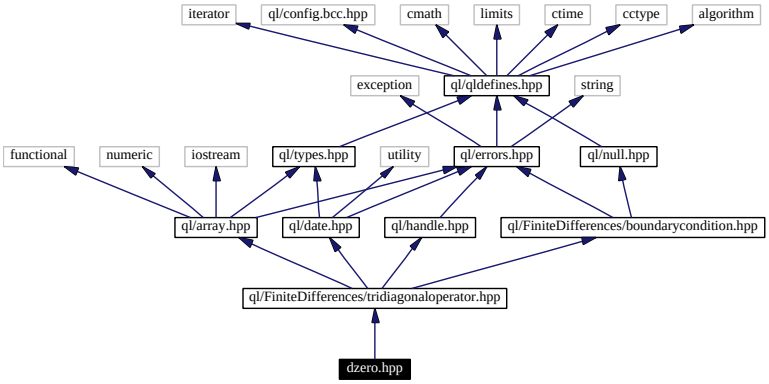
Full path:
ql/FiniteDifferences/dplusdminus.hpp

12.88 dzero.hpp File Reference

D_0 matricial representation.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for dzero.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.88.1 Detailed Description

Full path:
ql/FiniteDifferences/dzero.hpp

12.89 errors.hpp File Reference

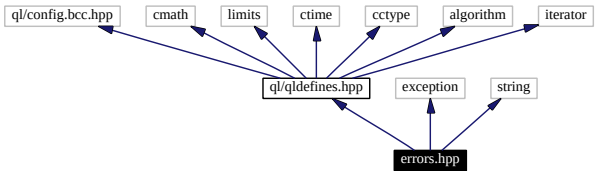
Classes and functions for error handling.

`#include <ql/qldefines.hpp>`

`#include <exception>`

`#include <string>`

Include dependency graph for errors.hpp:



Namespaces

- namespace QuantLib

Defines

- #define QL_ASSERT(condition, description)

  throw an error if the given condition is not verified \relates Error.

- #define QL_REQUIRE(condition, description)

  throw an error if the given pre-condition is not verified \relates Error.

- #define QL_ENSURE(condition, description)

  throw an error if the given post-condition is not verified \relates Error.

12.89.1 Detailed Description

Full path:
ql/errors.hpp

12.89.2 Define Documentation

12.89.2.1 #define QL_ASSERT(condition, description)

Value:

```
do { \
        if (!(condition)) \
            throw QuantLib::AssertionFailedError(description); \
    } while (false)
```

12.89.2.2 #define QL_REQUIRE(condition, description)

Value:

```
do { \
        if (!(condition)) \
            throw QuantLib::PreconditionNotSatisfiedError(description); \
    } while (false)
```

Examples:
DiscreteHedging.cpp, and swapvaluation.cpp.

12.89.2.3 #define QL_ENSURE(condition, description)

Value:

```
do { \
        if (!(condition)) \
            throw QuantLib::PostconditionNotSatisfiedError(description); \
    } while (false)
```

12.90 euribor.hpp File Reference

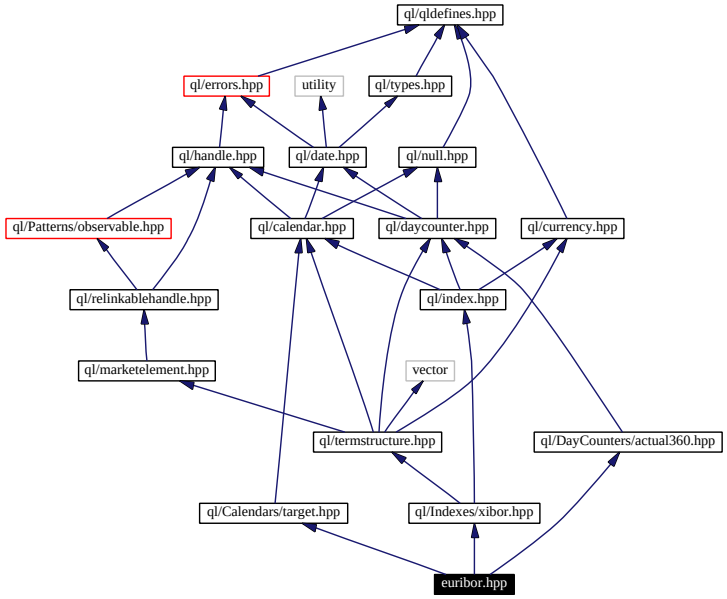
Euribor index.

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/target.hpp>`

`#include <ql/DayCounters/actual360.hpp>`

Include dependency graph for euribor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.90.1 Detailed Description

Full path:
ql/Indexes/euribor.hpp

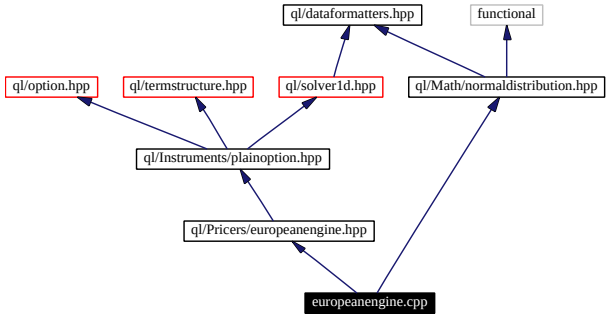
12.91 europeanengine.cpp File Reference

analytic pricing engine for European options.

`#include <ql/Pricers/europeanengine.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

Include dependency graph for europeanengine.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.91.1 Detailed Description

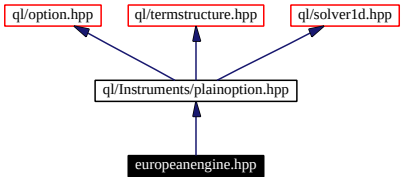
Full path:
ql/Pricers/europeanengine.cpp

12.92 europeanengine.hpp File Reference

analytic pricing engine for European options.

`#include <ql/Instruments/plainoption.hpp>`

Include dependency graph for europeanengine.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.92.1 Detailed Description

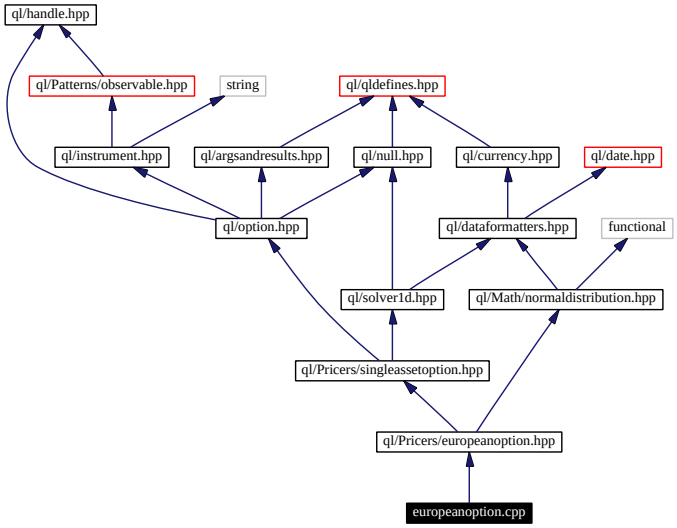
Full path:
ql/Pricers/europeanengine.hpp

12.93 europeanoption.cpp File Reference

european option.

`#include <ql/Pricers/europeanoption.hpp>`

Include dependency graph for europeanoption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.93.1 Detailed Description

Full path:
ql/Pricers/europeanoption.cpp

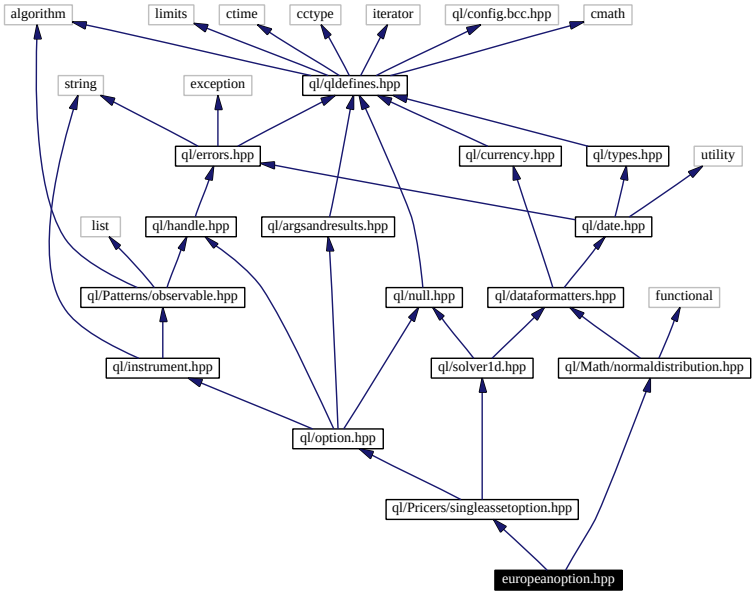
12.94 europeanoption.hpp File Reference

european option.

`#include <ql/Pricers/singleassetoption.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

Include dependency graph for europeanoption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.94.1 Detailed Description

Full path:
ql/Pricers/europeanoption.hpp

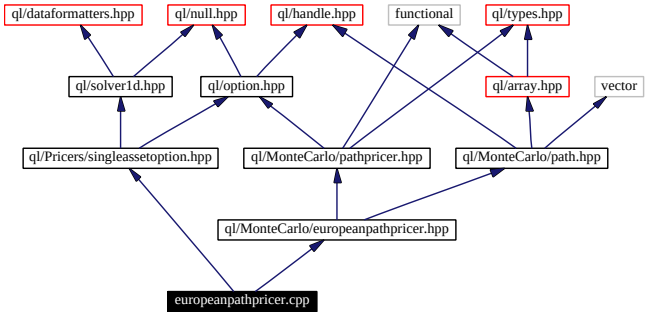
12.95 europeanpathpricer.cpp File Reference

path pricer for European options.

`#include <ql/MonteCarlo/europeanpathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for europeanpathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.95.1 Detailed Description

Full path:
ql/MonteCarlo/europeanpathpricer.cpp

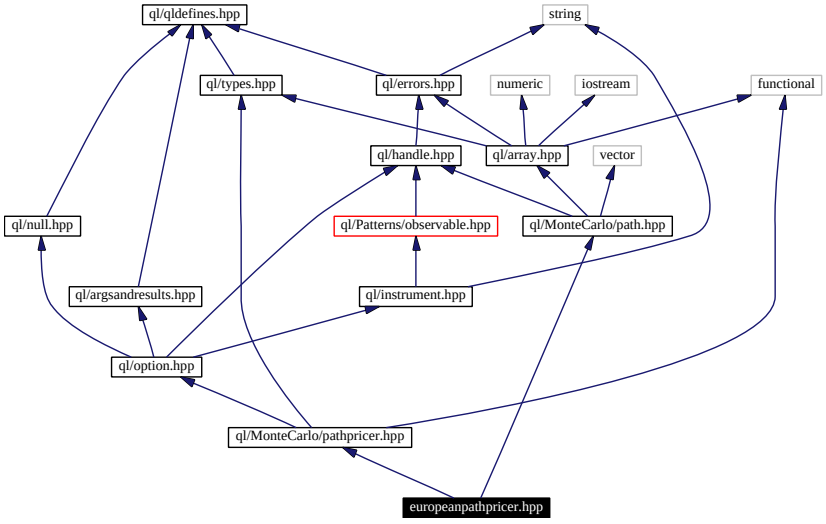
12.96 europeanpathpricer.hpp File Reference

path pricer for European options.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/path.hpp>`

Include dependency graph for europeanpathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.96.1 Detailed Description

Full path:
ql/MonteCarlo/europeanpathpricer.hpp

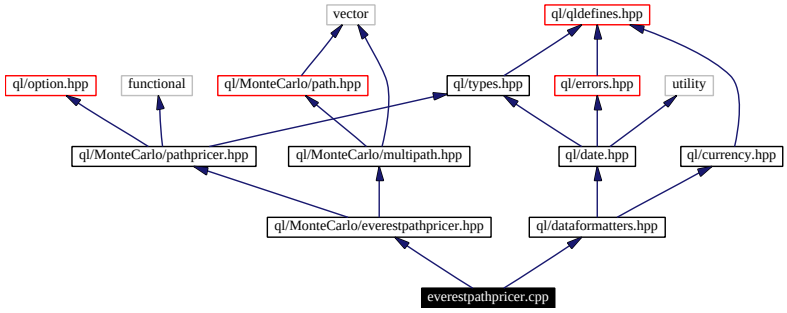
12.97 everestpathpricer.cpp File Reference

path pricer for European-type Everest option.

`#include <ql/MonteCarlo/everestpathpricer.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for everestpathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.97.1 Detailed Description

Full path:

MonteCarlo/everestpathpricer.cpp

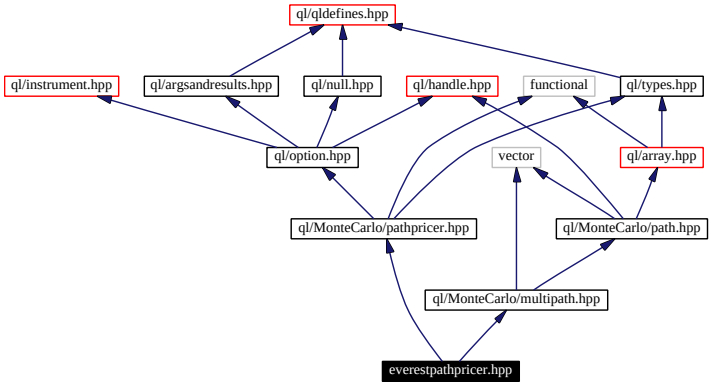
12.98 everestpathpricer.hpp File Reference

path pricer for European-type Everest option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/multipath.hpp>`

Include dependency graph for everestpathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.98.1 Detailed Description

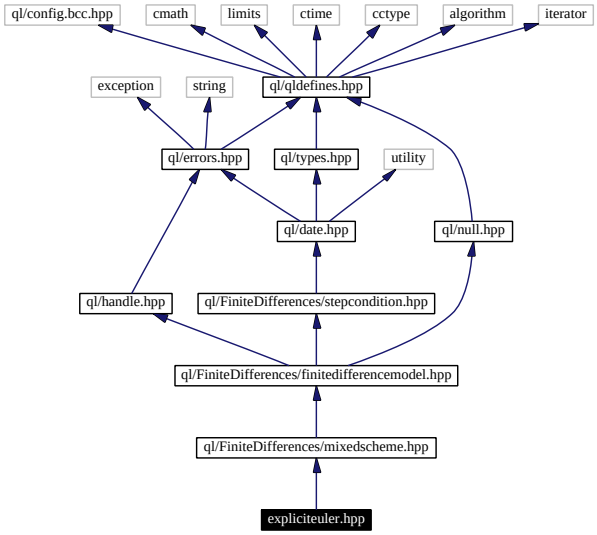
Full path:
ql/MonteCarlo/everestpathpricer.hpp

12.99 expliciteuler.hpp File Reference

explicit Euler scheme for finite difference methods.

`#include <ql/FiniteDifferences/mixedscheme.hpp>`

Include dependency graph for expliciteuler.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.99.1 Detailed Description

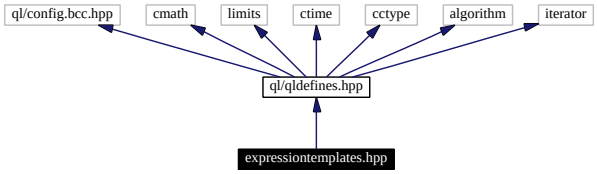
Full path:
ql/FiniteDifferences/expliciteuler.hpp

12.100 expressiontemplates.hpp File Reference

expression template implementation.

`#include <ql/qldefines.hpp>`

Include dependency graph for expressiontemplates.hpp:



Namespaces

- namespace QuantLib

12.100.1 Detailed Description

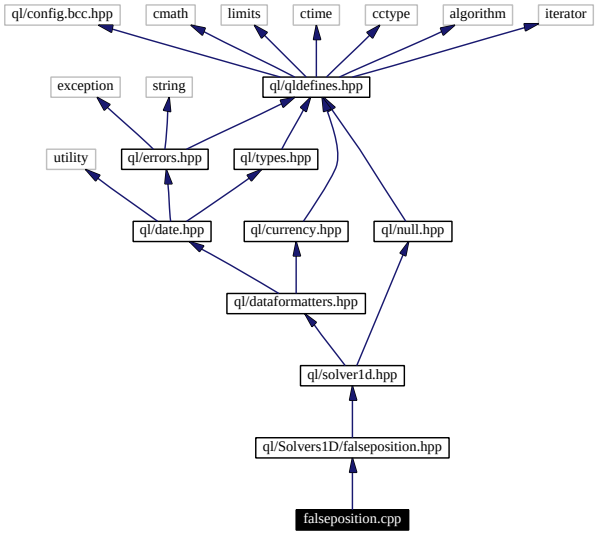
Full path:
ql/expressiontemplates.hpp

12.101 falseposition.cpp File Reference

false-position 1-D solver.

`#include <ql/Solvers1D/falseposition.hpp>`

Include dependency graph for falseposition.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.101.1 Detailed Description

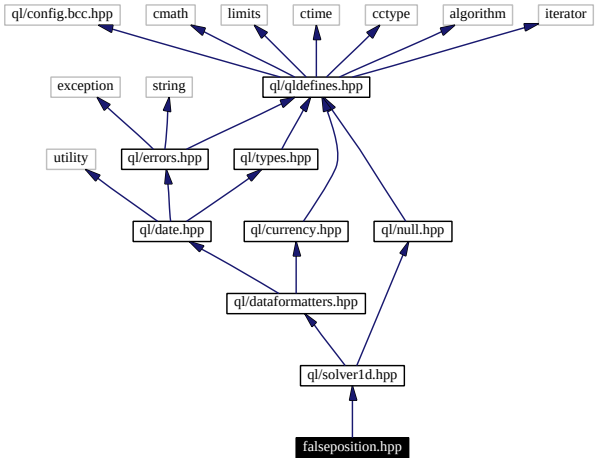
Full path:
ql/Solvers1D/falseposition.cpp

12.102 falseposition.hpp File Reference

false-position 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for falseposition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.102.1 Detailed Description

Full path:
ql/Solvers1D/falseposition.hpp

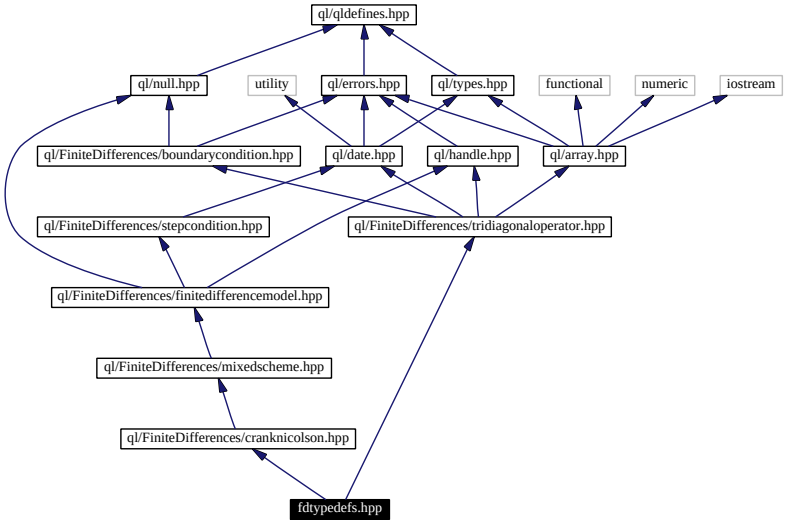
12.103 fdtypedefs.hpp File Reference

default choices for template instantiations.

`#include <ql/FiniteDifferences/cranknicolson.hpp>`

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

Include dependency graph for fdtypedefs.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.103.1 Detailed Description

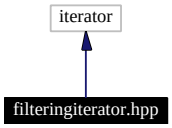
Full path:
ql/FiniteDifferences/fdtypedefs.hpp

12.104 filteringiterator.hpp File Reference

Iterator filtering undesired data.

`#include <iterator>`

Include dependency graph for filteringiterator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.104.1 Detailed Description

Full path:
ql/Utilities/filteringiterator.hpp

12.105 finitedifferencemodel.hpp File Reference

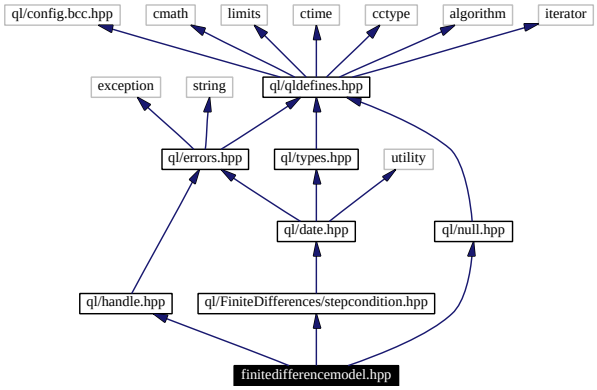
generic finite difference model.

`#include <ql/FiniteDifferences/stepcondition.hpp>`

`#include <ql/handle.hpp>`

`#include <ql/null.hpp>`

Include dependency graph for finitedifferencemodel.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.105.1 Detailed Description

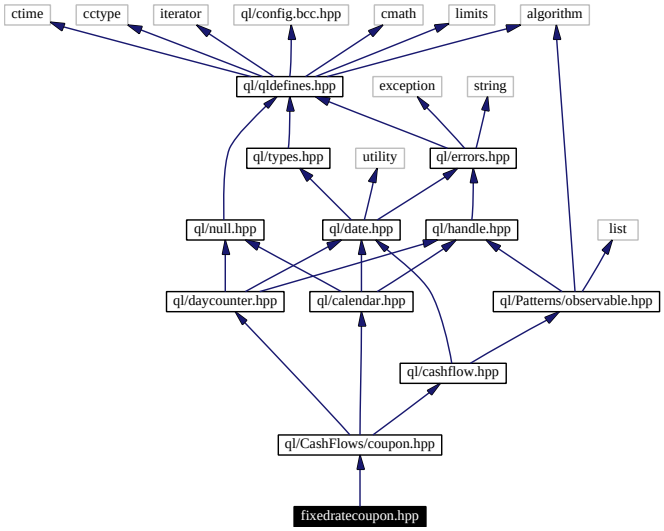
Full path:
ql/FiniteDifferences/finitedifferencemodel.hpp

12.106 fixedratecoupon.hpp File Reference

Coupon paying a fixed annual rate.

`#include <ql/CashFlows/coupon.hpp>`

Include dependency graph for fixedratecoupon.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.106.1 Detailed Description

Full path:
ql/CashFlows/fixedratecoupon.hpp

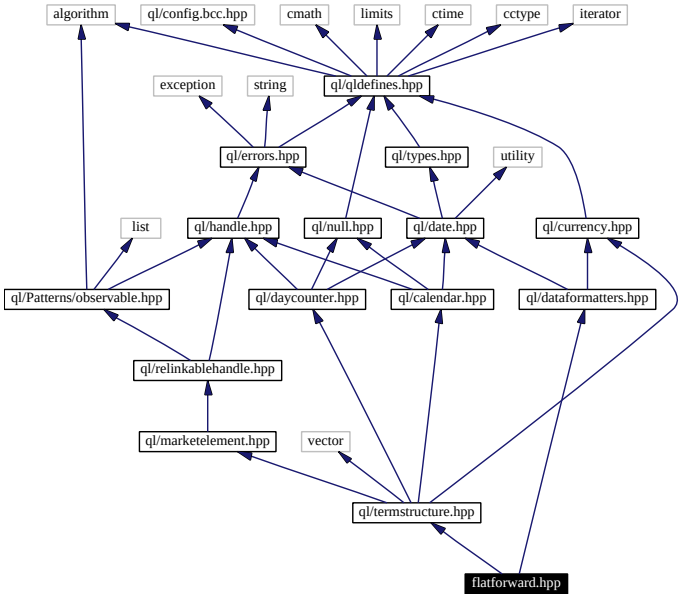
12.107 flatforward.hpp File Reference

flat forward rate term structure.

`#include <ql/termstructure.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for flatforward.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::TermStructures

12.107.1 Detailed Description

Full path:
ql/TermStructures/flatforward.hpp

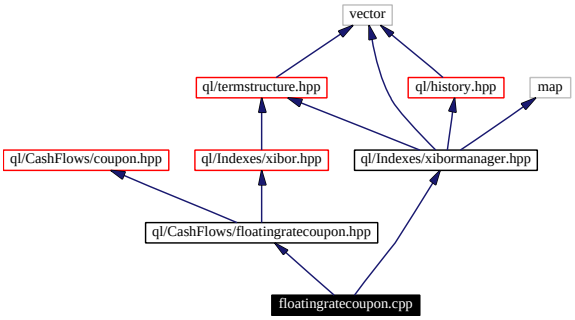
12.108 floatingratecoupon.cpp File Reference

Coupon at par on a term structure.

`#include <ql/CashFlows/floatingratecoupon.hpp>`

`#include <ql/Indexes/xibormanager.hpp>`

Include dependency graph for floatingratecoupon.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.108.1 Detailed Description

Full path:
ql/CashFlows/floatingratecoupon.cpp

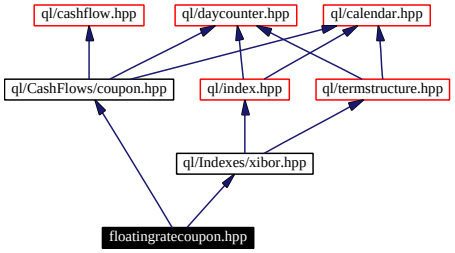
12.109 floatingratecoupon.hpp File Reference

Coupon at par on a term structure.

`#include <ql/CashFlows/coupon.hpp>`

`#include <ql/Indexes/xibor.hpp>`

Include dependency graph for floatingratecoupon.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.109.1 Detailed Description

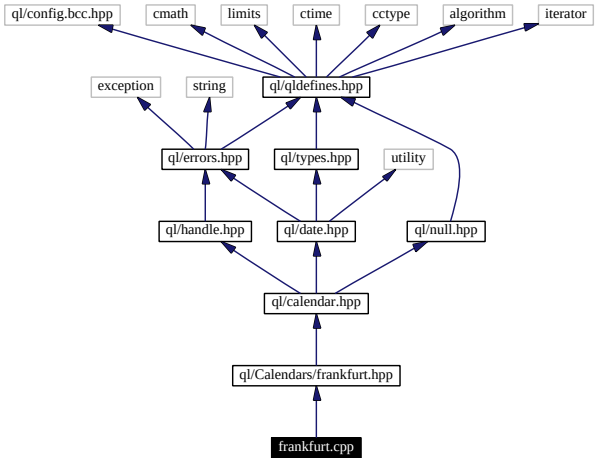
Full path:
ql/CashFlows/floatingratecoupon.hpp

12.110 frankfurt.cpp File Reference

Frankfurt calendar.

`#include <ql/Calendars/frankfurt.hpp>`

Include dependency graph for frankfurt.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.110.1 Detailed Description

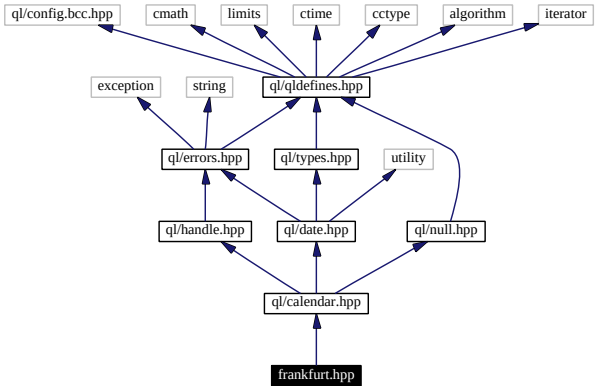
Full path:
Calendars/frankfurt.cpp

12.111 frankfurt.hpp File Reference

Frankfurt calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for frankfurt.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.111.1 Detailed Description

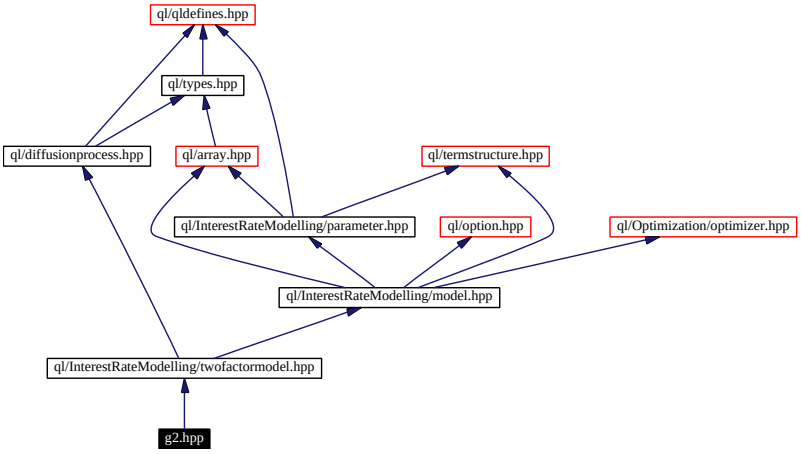
Full path:
ql/Calendars/frankfurt.hpp

12.112 g2.hpp File Reference

Two-additive-factor Gaussian Model G2++.

`#include "ql/InterestRateModelling/twofactormodel.hpp"`

Include dependency graph for g2.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.112.1 Detailed Description

Full path:
ql/InterestRateModelling/TwoFactorModels/g2.hpp

12.113 gbplibor.hpp File Reference

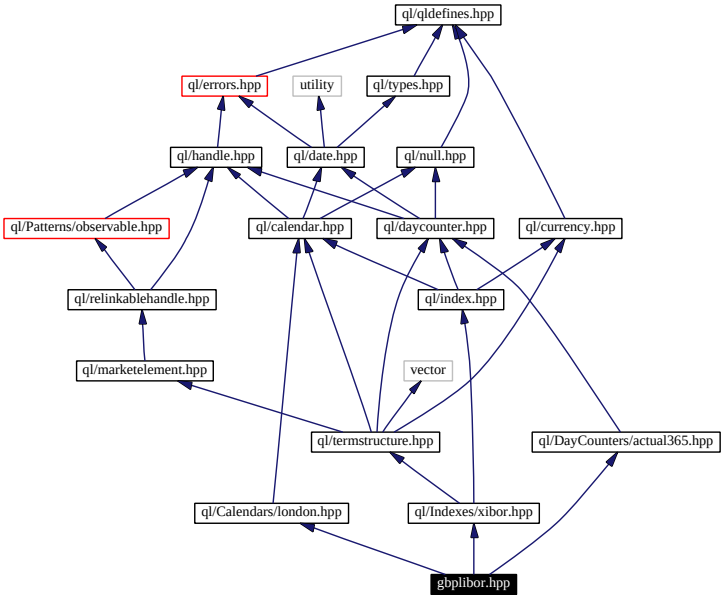
GBP Libor index.

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/london.hpp>`

`#include <ql/DayCounters/actual365.hpp>`

Include dependency graph for gbplibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.113.1 Detailed Description

Full path:
ql/Indexes/gbplibor.hpp

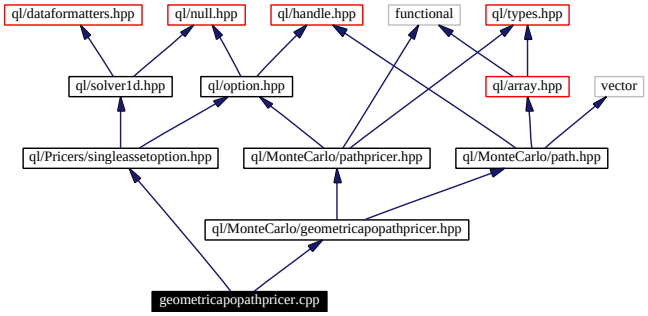
12.114 geometricapopathpricer.cpp File Reference

path pricer for geometric average price option.

`#include <ql/MonteCarlo/geometricapopathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for geometricapopathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.114.1 Detailed Description

Full path:
ql/MonteCarlo/geometricapopathpricer.cpp

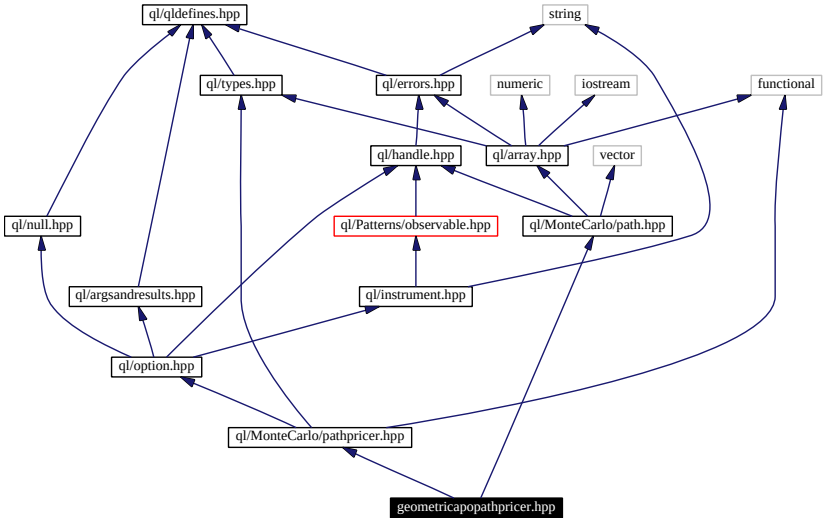
12.115 geometricapopathpricer.hpp File Reference

path pricer for geometric average price option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/path.hpp>`

Include dependency graph for geometricapopathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.115.1 Detailed Description

Full path:
ql/MonteCarlo/geometricapopathpricer.hpp

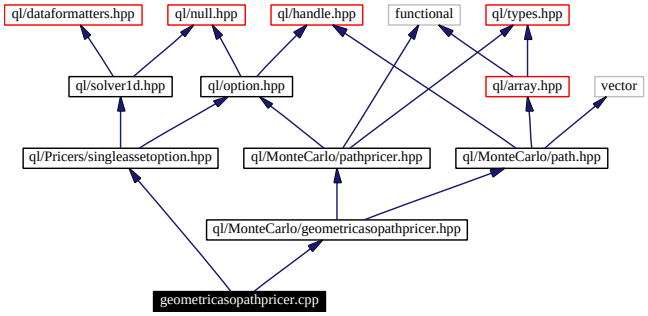
12.116 geometricasopathpricer.cpp File Reference

path pricer for geometric average strike option.

`#include <ql/MonteCarlo/geometricasopathpricer.hpp>`

`#include <ql/Pricers/singleassetoption.hpp>`

Include dependency graph for geometricasopathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.116.1 Detailed Description

Full path:
ql/MonteCarlo/geometricasopathpricer.cpp

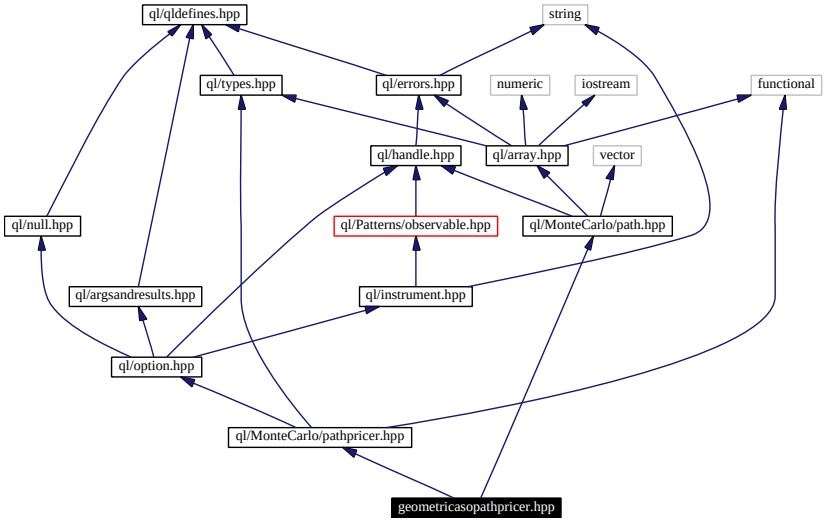
12.117 geometricasopathpricer.hpp File Reference

path pricer for geometric average strike option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/path.hpp>`

Include dependency graph for geometricasopathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.117.1 Detailed Description

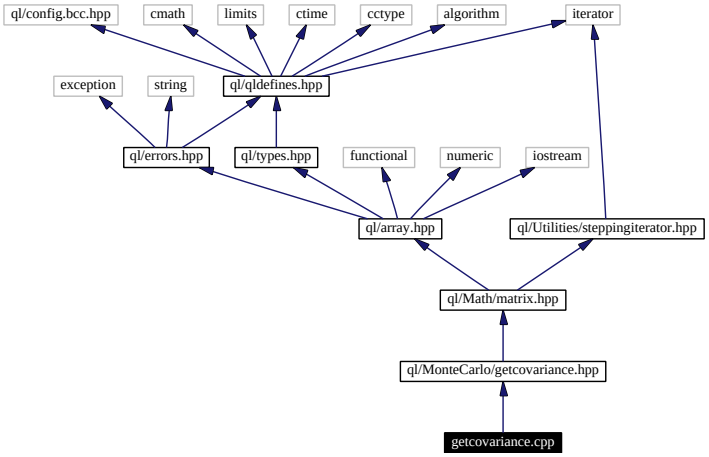
Full path:
ql/MonteCarlo/geometricasopathpricer.hpp

12.118 getcovariance.cpp File Reference

Covariance matrix calculation.

`#include <ql/MonteCarlo/getcovariance.hpp>`

Include dependency graph for getcovariance.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.118.1 Detailed Description

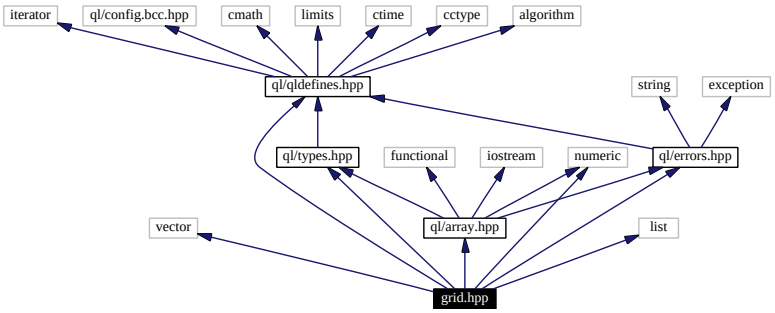
Full path:
ql/MonteCarlo/getcovariance.cpp

12.119 grid.hpp File Reference

Grid classes with useful constructors for trees and finite diffs.

```
#include <ql/array.hpp>
#include <ql/errors.hpp>
#include <ql/qldefines.hpp>
#include <ql/types.hpp>
#include <list>
#include <numeric>
#include <vector>
```

Include dependency graph for grid.hpp:



Namespaces

- namespace QuantLib

12.119.1 Detailed Description

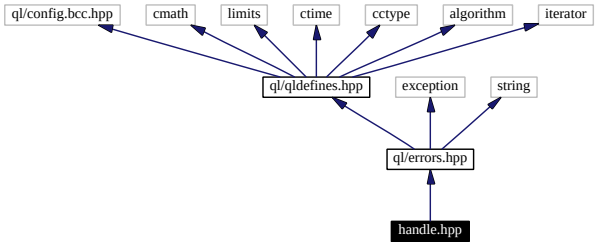
Full path:
ql/grid.hpp

12.120 handle.hpp File Reference

Reference-counted pointer.

`#include <ql/errors.hpp>`

Include dependency graph for handle.hpp:



Namespaces

- namespace QuantLib

12.120.1 Detailed Description

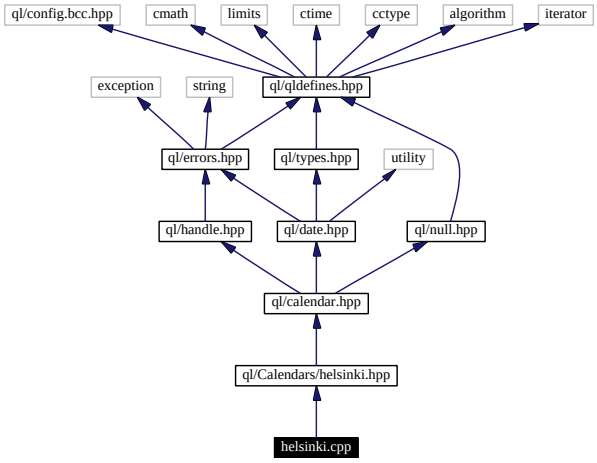
Full path:
ql/handle.hpp

12.121 helsinki.cpp File Reference

Helsinki calendar.

`#include <ql/Calendars/helsinki.hpp>`

Include dependency graph for helsinki.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.121.1 Detailed Description

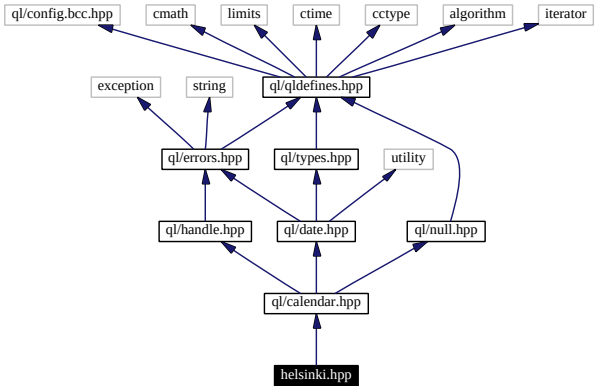
Full path:
Calendars/helsinki.cpp

12.122 helsinki.hpp File Reference

Helsinki calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for helsinki.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.122.1 Detailed Description

Full path:
ql/Calendars/helsinki.hpp

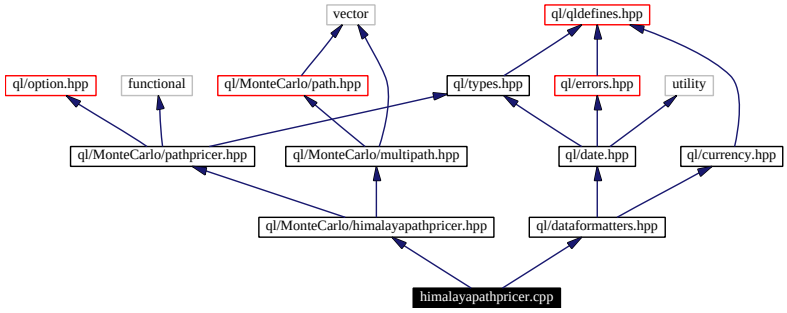
12.123 himalayapathpricer.cpp File Reference

multipath pricer for European-type Himalaya option.

`#include <ql/MonteCarlo/himalayapathpricer.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for himalayapathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.123.1 Detailed Description

Full path:
ql/MonteCarlo/himalayapathpricer.cpp

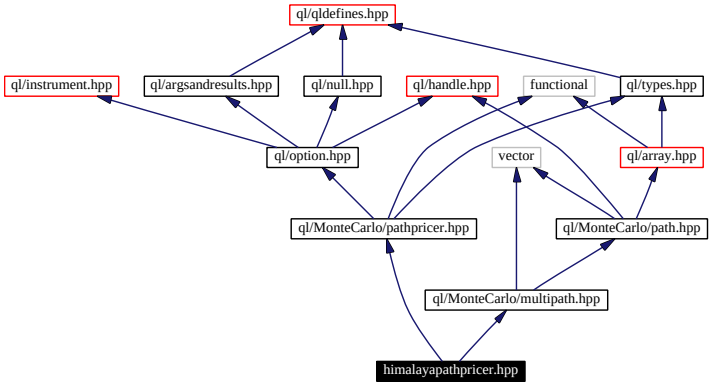
12.124 himalayapathpricer.hpp File Reference

multipath pricer for European-type Himalaya option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/multipath.hpp>`

Include dependency graph for himalayapathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.124.1 Detailed Description

Full path:
ql/MonteCarlo/himalayapathpricer.hpp

12.125 history.hpp File Reference

history class.

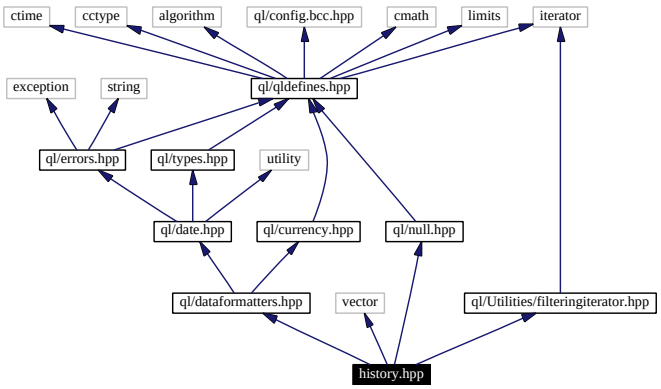
`#include <ql/null.hpp>`

`#include <ql/Utilities/filteringiterator.hpp>`

`#include <ql/dataformatters.hpp>`

`#include <vector>`

Include dependency graph for history.hpp:



Namespaces

- namespace QuantLib

12.125.1 Detailed Description

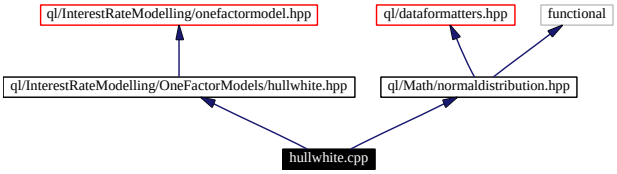
Full path:
ql/history.hpp

12.126 hullwhite.cpp File Reference

Hull & White model.

```
#include "ql/InterestRateModelling/OneFactorModels/hullwhite.hpp"
#include "ql/Math/normaldistribution.hpp"
```

Include dependency graph for hullwhite.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.126.1 Detailed Description

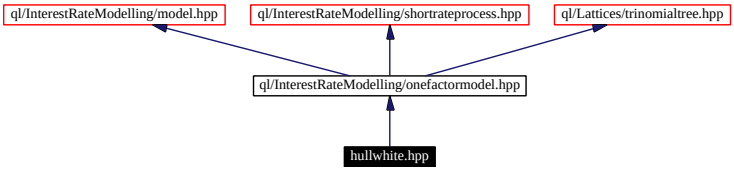
Full path:
ql/InterestRateModelling/OneFactorModels/hullwhite.cpp

12.127 hullwhite.hpp File Reference

Hull & White (HW) model.

`#include "ql/InterestRateModelling/onefactormodel.hpp"`

Include dependency graph for hullwhite.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.127.1 Detailed Description

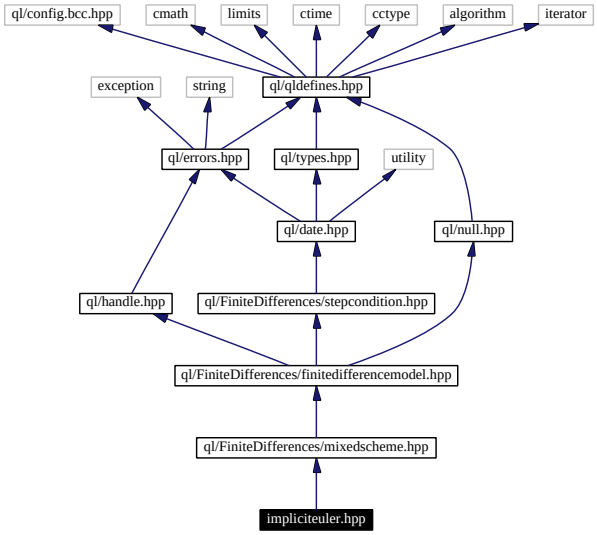
Full path:
ql/InterestRateModelling/OneFactorModels/hullwhite.hpp

12.128 impliciteuler.hpp File Reference

implicit Euler scheme for finite difference methods.

`#include <ql/FiniteDifferences/mixedscheme.hpp>`

Include dependency graph for impliciteuler.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.128.1 Detailed Description

Full path:
ql/FiniteDifferences/impliciteuler.hpp

12.129 index.hpp File Reference

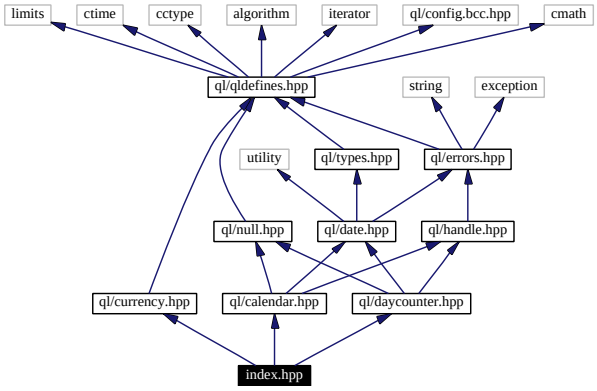
purely virtual base class for indexes.

`#include <ql/calendar.hpp>`

`#include <ql/currency.hpp>`

`#include <ql/daycounter.hpp>`

Include dependency graph for index.hpp:



Namespaces

- namespace QuantLib::Indexes
- namespace QuantLib

12.129.1 Detailed Description

Full path:
ql/index.hpp

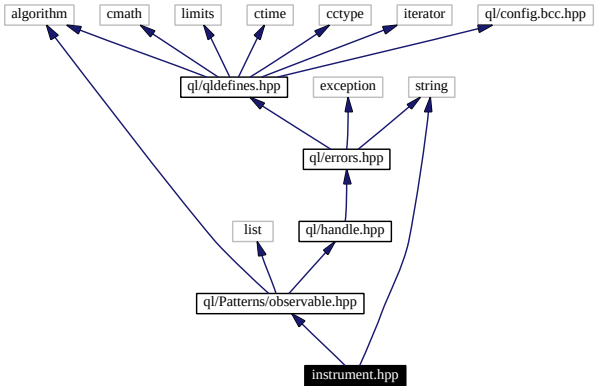
12.130 instrument.hpp File Reference

Abstract instrument class.

`#include <ql/Patterns/observable.hpp>`

`#include <string>`

Include dependency graph for instrument.hpp:



Namespaces

- namespace QuantLib::Instruments
- namespace QuantLib

12.130.1 Detailed Description

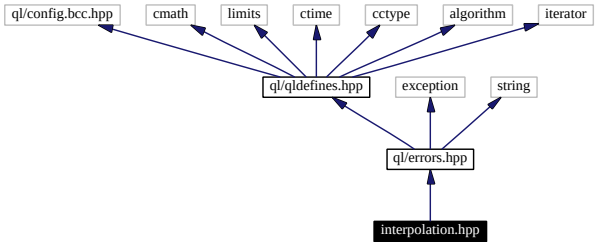
Full path:
ql/instrument.hpp

12.131 interpolation.hpp File Reference

abstract base classes for interpolations.

`#include <ql/errors.hpp>`

Include dependency graph for interpolation.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.131.1 Detailed Description

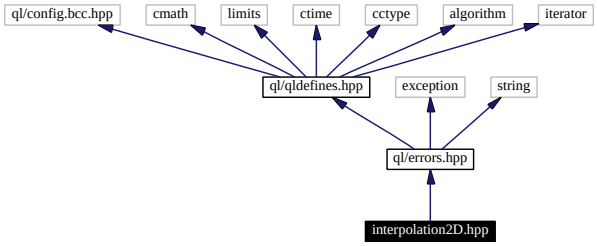
Full path:
ql/Math/interpolation.hpp

12.132 interpolation2D.hpp File Reference

abstract base classes for 2-D interpolations.

`#include <ql/errors.hpp>`

Include dependency graph for interpolation2D.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.132.1 Detailed Description

Full path:
ql/Math/interpolation2D.hpp

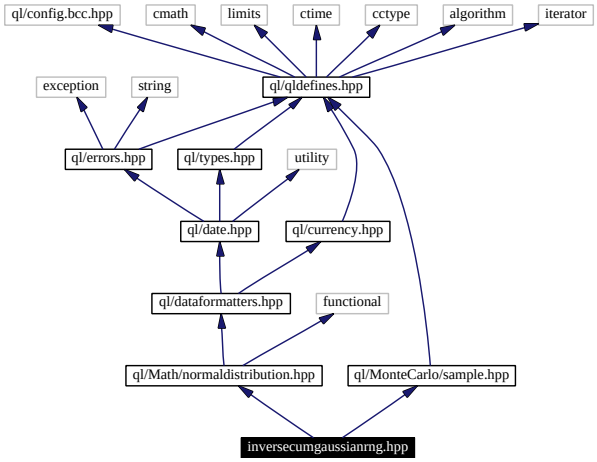
12.133 inversecumgaussianrng.hpp File Reference

Inverse cumulative Gaussian random-number generator.

`#include <ql/Math/normaldistribution.hpp>`

`#include <ql/MonteCarlo/sample.hpp>`

Include dependency graph for inversecumgaussianrng.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.133.1 Detailed Description

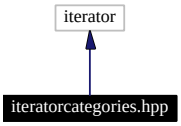
Full path:
ql/RandomNumbers/inversecumgaussianrng.hpp

12.134 iteratorcategories.hpp File Reference

Lowest common denominator between two iterator categories.

`#include <iterator>`

Include dependency graph for iteratorcategories.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.134.1 Detailed Description

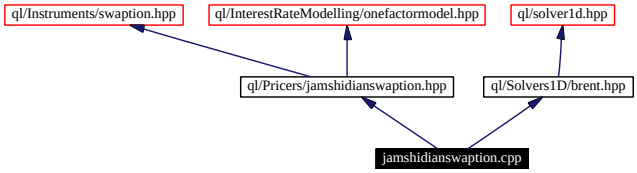
Full path:
ql/Utilities/iteratorcategories.hpp

12.135 jamshidianswaption.cpp File Reference

Swaption pricer using Jamshidian's decomposition.

```
#include "ql/Pricers/jamshidianswaption.hpp"
#include "ql/Solvers1D/brent.hpp"
```

Include dependency graph for jamshidianswaption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.135.1 Detailed Description

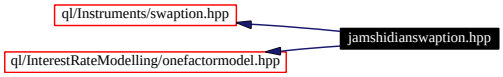
Full path:
ql/Pricers/jamshidianswaption.cpp

12.136 jamshidianswaption.hpp File Reference

Swaption pricer using Jamshidian's decomposition.

```
#include "ql/Instruments/swaption.hpp"
#include "ql/InterestRateModelling/onefactormodel.hpp"
```

Include dependency graph for jamshidianswaption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.136.1 Detailed Description

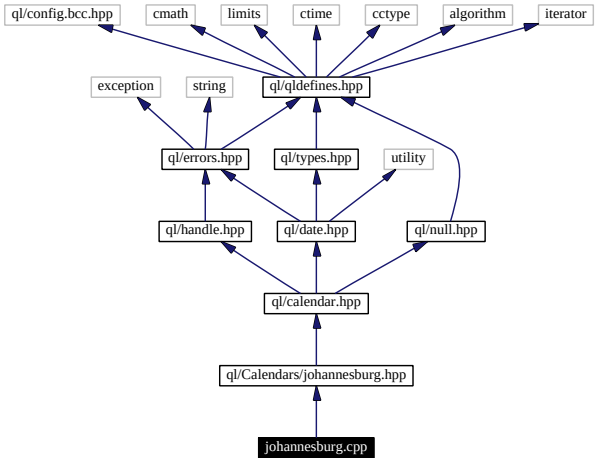
Full path:
ql/Pricers/jamshidianswaption.hpp

12.137 johannesburg.cpp File Reference

Johannesburg calendar.

`#include <ql/Calendars/johannesburg.hpp>`

Include dependency graph for johannesburg.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.137.1 Detailed Description

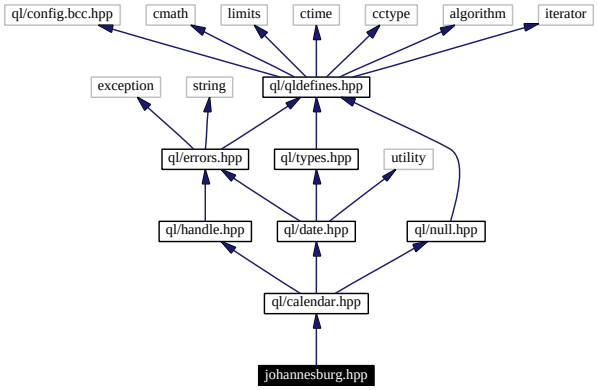
Full path:
Calendars/johannesburg.cpp

12.138 johannesburg.hpp File Reference

Johannesburg calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for johannesburg.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.138.1 Detailed Description

Full path:
ql/Calendars/johannesburg.hpp

12.139 jpylibor.hpp File Reference

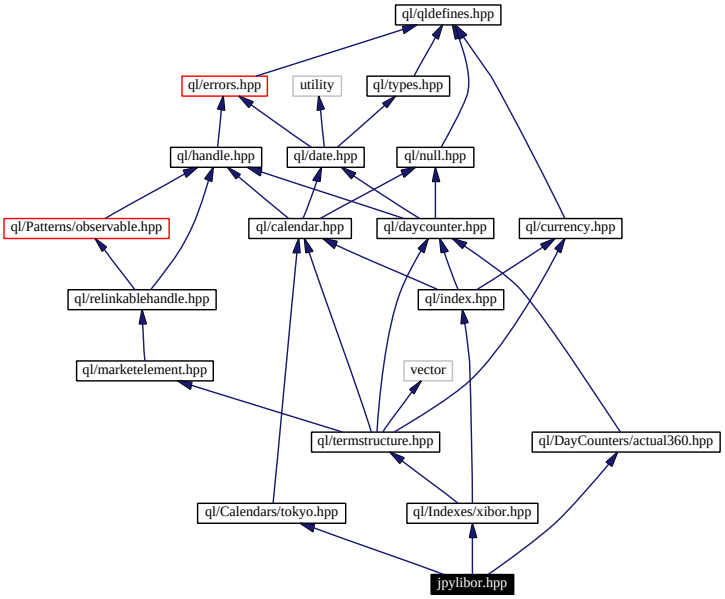
JPY Libor index (Also known as TIBOR, check settlement days).

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/tokyo.hpp>`

`#include <ql/DayCounters/actual360.hpp>`

Include dependency graph for jpylibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.139.1 Detailed Description

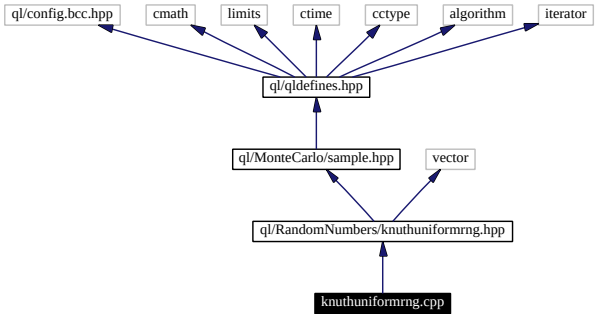
Full path:
ql/Indexes/jpylibor.hpp

12.140 knuthuniformrng.cpp File Reference

Knuth uniform random number generator.

`#include <ql/RandomNumbers/knuthuniformrng.hpp>`

Include dependency graph for knuthuniformrng.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.140.1 Detailed Description

Full path:
ql/RandomNumbers/knuthuniformrng.cpp

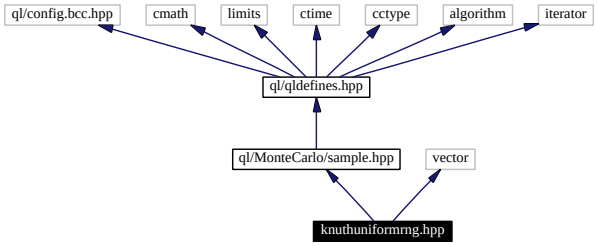
12.141 knuthuniformrng.hpp File Reference

Knuth uniform random number generator.

`#include <ql/MonteCarlo/sample.hpp>`

`#include <vector>`

Include dependency graph for knuthuniformrng.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.141.1 Detailed Description

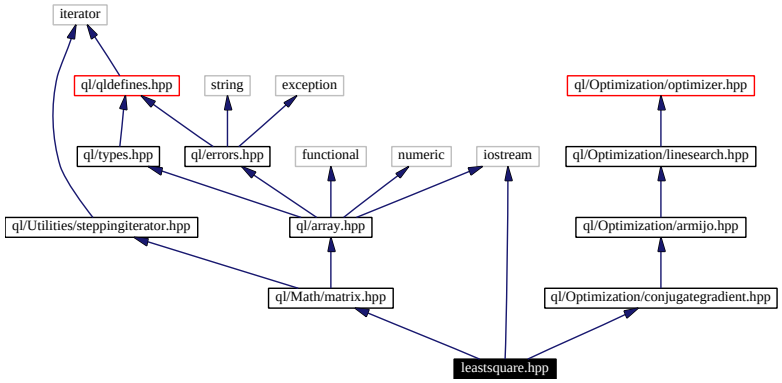
Full path:
ql/RandomNumbers/knuthuniformrng.hpp

12.142 leastsquare.hpp File Reference

Least square cost function.

```
#include "ql/Math/matrix.hpp"
#include "ql/Optimization/conjugategradient.hpp"
#include <iostream>
```

Include dependency graph for leastsquare.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.142.1 Detailed Description

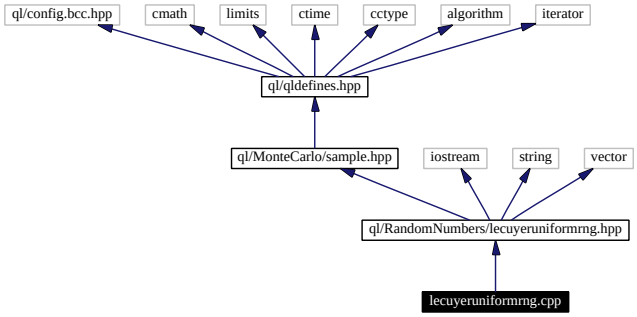
Full path:
ql/Optimization/leastsquare.hpp

12.143 lecuyeruniformrng.cpp File Reference

L'Ecuyer uniform random number generator.

`#include <ql/RandomNumbers/lecuyeruniformrng.hpp>`

Include dependency graph for lecuyeruniformrng.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.143.1 Detailed Description

Full path:
ql/RandomNumbers/lecuyeruniformrng.cpp

12.144 lecuyeruniformrng.hpp File Reference

L'Ecuyer uniform random number generator.

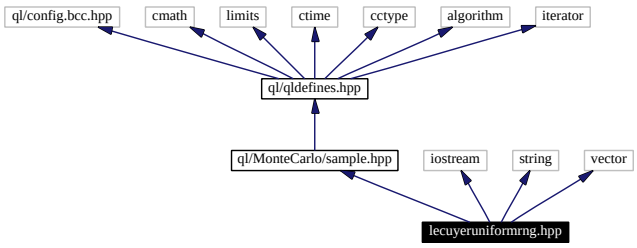
`#include <ql/MonteCarlo/sample.hpp>`

`#include <iostream>`

`#include <string>`

`#include <vector>`

Include dependency graph for lecuyeruniformrng.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.144.1 Detailed Description

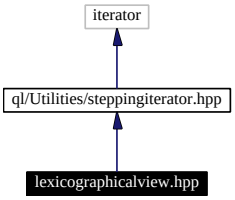
Full path:
ql/RandomNumbers/lecuyeruniformrng.hpp

12.145 lexicographicalview.hpp File Reference

Lexicographical 2-D view of a contiguous set of data.

`#include <ql/Utilities/steppingiterator.hpp>`

Include dependency graph for lexicographicalview.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.145.1 Detailed Description

Full path:
ql/Math/lexicographicalview.hpp

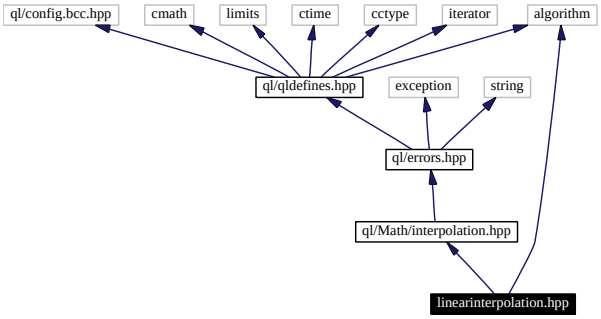
12.146 linearinterpolation.hpp File Reference

linear interpolation between discrete points.

`#include <ql/Math/interpolation.hpp>`

`#include <algorithm>`

Include dependency graph for linearinterpolation.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.146.1 Detailed Description

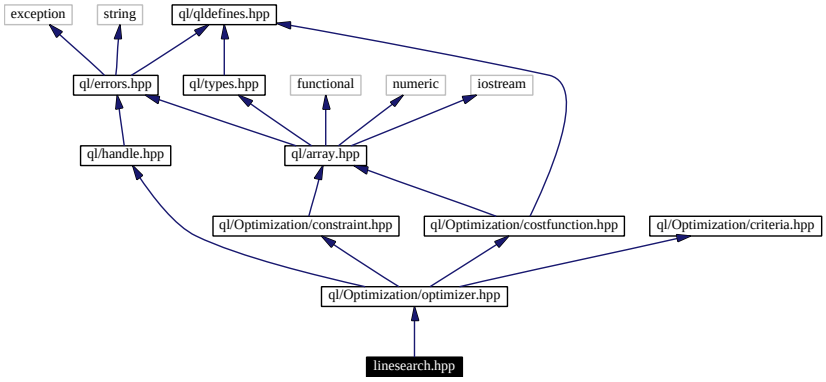
Full path:
ql/Math/linearinterpolation.hpp

12.147 linesearch.hpp File Reference

Line search abstract class.

`#include "ql/Optimization/optimizer.hpp"`

Include dependency graph for linesearch.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.147.1 Detailed Description

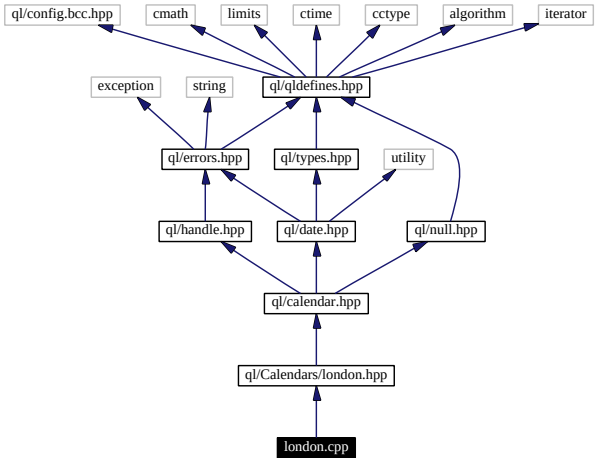
Full path:
ql/Optimization/linesearch.hpp

12.148 london.cpp File Reference

London calendar.

`#include <ql/Calendars/london.hpp>`

Include dependency graph for london.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.148.1 Detailed Description

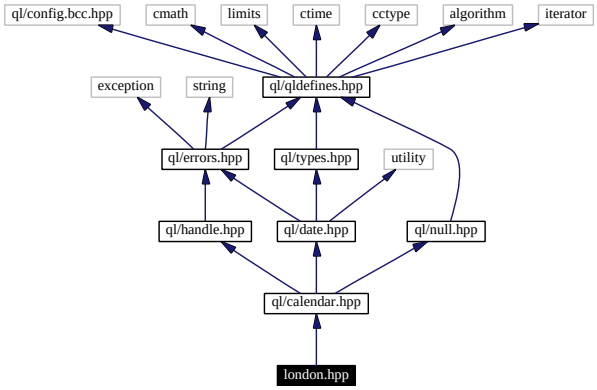
Full path:
Calendars/london.cpp

12.149 london.hpp File Reference

London calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for london.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.149.1 Detailed Description

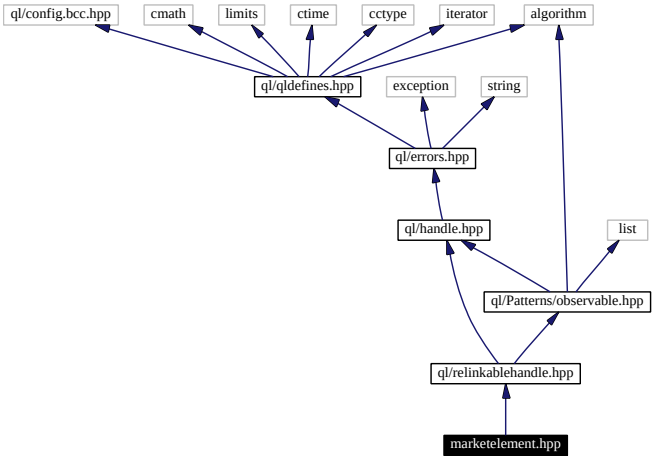
Full path:
ql/Calendars/london.hpp

12.150 marketelement.hpp File Reference

purely virtual base class for market observables.

`#include <ql/relinkablehandle.hpp>`

Include dependency graph for marketelement.hpp:



Namespaces

- namespace QuantLib

12.150.1 Detailed Description

Full path:
ql/marketelement.hpp

12.151 mathf.cpp File Reference

math functions.

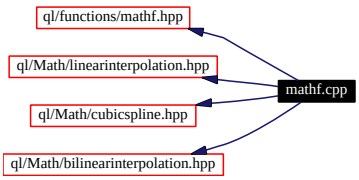
`#include <ql/functions/mathf.hpp>`

`#include <ql/Math/linearinterpolation.hpp>`

`#include <ql/Math/cubicspline.hpp>`

`#include <ql/Math/bilinearinterpolation.hpp>`

Include dependency graph for mathf.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Functions**

12.151.1 Detailed Description

Full path:
ql/functions/mathf.cpp

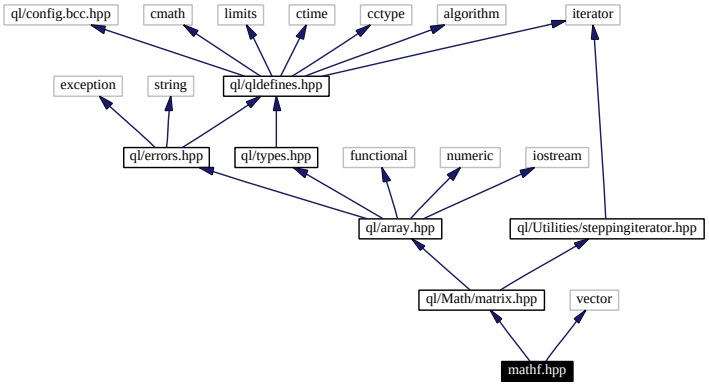
12.152 mathf.hpp File Reference

math functions.

`#include <ql/Math/matrix.hpp>`

`#include <vector>`

Include dependency graph for mathf.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Functions**

12.152.1 Detailed Description

Full path:
ql/functions/mathf.hpp

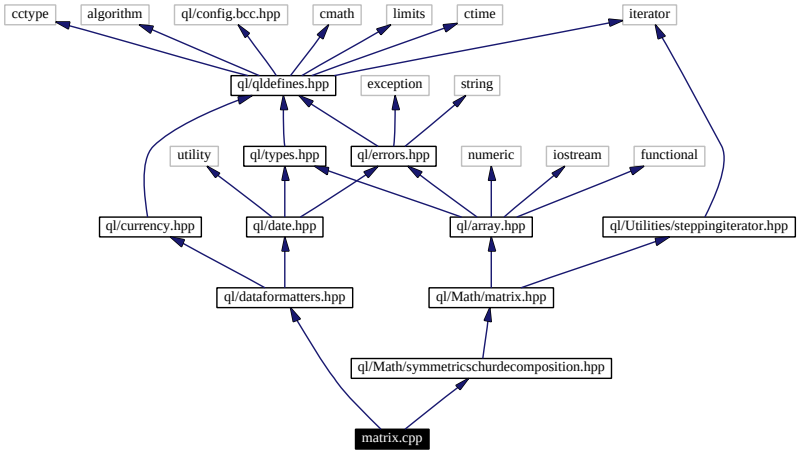
12.153 matrix.cpp File Reference

matrix used in linear algebra.

`#include <ql/Math/symmetricschurdecomposition.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for matrix.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.153.1 Detailed Description

Full path:
ql/Math/matrix.cpp

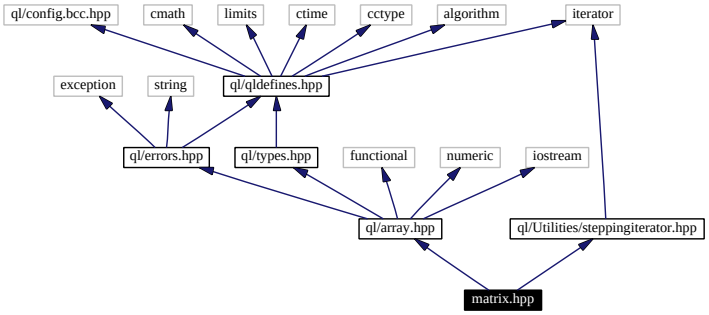
12.154 matrix.hpp File Reference

matrix used in linear algebra.

`#include <ql/array.hpp>`

`#include <ql/Utilities/steppingiterator.hpp>`

Include dependency graph for matrix.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.154.1 Detailed Description

Full path:
ql/Math/matrix.hpp

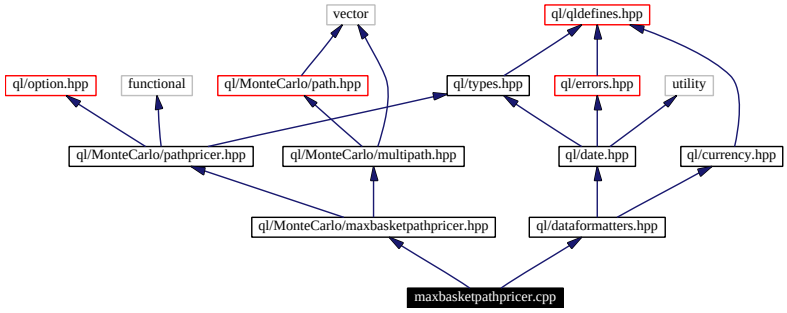
12.155 maxbasketpathpricer.cpp File Reference

multipath pricer for max basket option.

`#include <ql/MonteCarlo/maxbasketpathpricer.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for maxbasketpathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.155.1 Detailed Description

Full path:

MonteCarlo/basketpathpricer.cpp

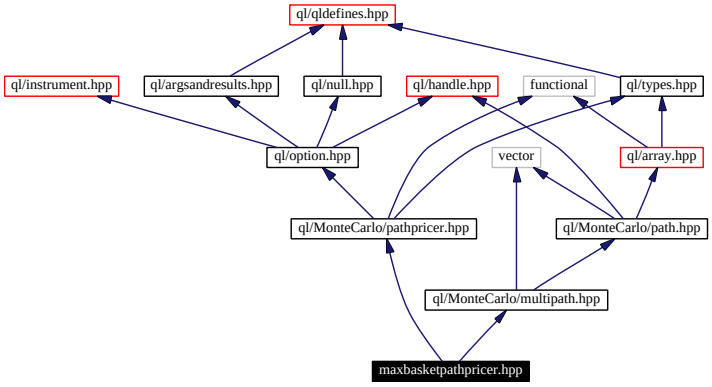
12.156 maxbasketpathpricer.hpp File Reference

multipath pricer for max basket option.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/multipath.hpp>`

Include dependency graph for maxbasketpathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.156.1 Detailed Description

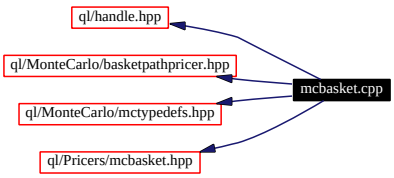
Full path:
ql/MonteCarlo/maxbasketpathpricer.hpp

12.157 mcbasket.cpp File Reference

simple example of multi-factor Monte Carlo pricer.

```
#include <ql/handle.hpp>
#include <ql/MonteCarlo/basketpathpricer.hpp>
#include <ql/MonteCarlo/mctypedefs.hpp>
#include <ql/Pricers/mcbasket.hpp>
```

Include dependency graph for mcbasket.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.157.1 Detailed Description

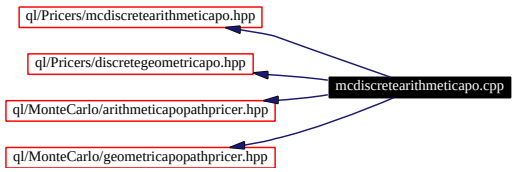
Full path:
ql/Pricers/mcbasket.cpp

12.158 mcdiscretearithmeticapo.cpp File Reference

Discrete Arithmetic Average Price Option.

```
#include <ql/Pricers/mcdiscretearithmeticapo.hpp>
#include <ql/Pricers/discretegeometricapo.hpp>
#include <ql/MonteCarlo/arithmeticapopathpricer.hpp>
#include <ql/MonteCarlo/geometricapopathpricer.hpp>
```

Include dependency graph for mcdiscretearithmeticapo.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.158.1 Detailed Description

Full path:
ql/Pricers/mcdiscretearithmeticapo.cpp

12.159 mcdiscretearithmeticapo.hpp File Reference

Discrete Arithmetic Average Price Option.

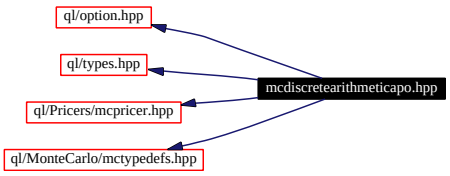
`#include <ql/option.hpp>`

`#include <ql/types.hpp>`

`#include <ql/Pricers/mcpricer.hpp>`

`#include <ql/MonteCarlo/mctypedefs.hpp>`

Include dependency graph for mcdiscretearithmeticapo.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.159.1 Detailed Description

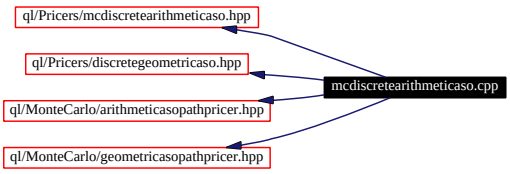
Full path:
ql/Pricers/mcdiscretearithmeticapo.hpp

12.160 mcdiscretearithmeticaso.cpp File Reference

Discrete Arithmetic Average Strike Option.

```
#include <ql/Pricers/mcdiscretearithmeticaso.hpp>
#include <ql/Pricers/discretegeometricaso.hpp>
#include <ql/MonteCarlo/arithmeticasopathpricer.hpp>
#include <ql/MonteCarlo/geometricasopathpricer.hpp>
```

Include dependency graph for mcdiscretearithmeticaso.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.160.1 Detailed Description

Full path:
ql/Pricers/mcdiscretearithmeticaso.cpp

12.161 mcdiscretearithmeticaso.hpp File Reference

Discrete Arithmetic Average Strike Option.

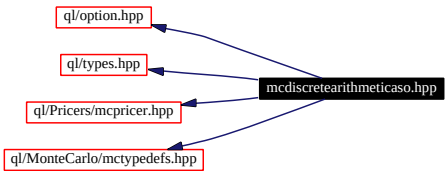
`#include <ql/option.hpp>`

`#include <ql/types.hpp>`

`#include <ql/Pricers/mcpricer.hpp>`

`#include <ql/MonteCarlo/mctypedefs.hpp>`

Include dependency graph for mcdiscretearithmeticaso.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.161.1 Detailed Description

Full path:
ql/Pricers/mcdiscretearithmeticaso.hpp

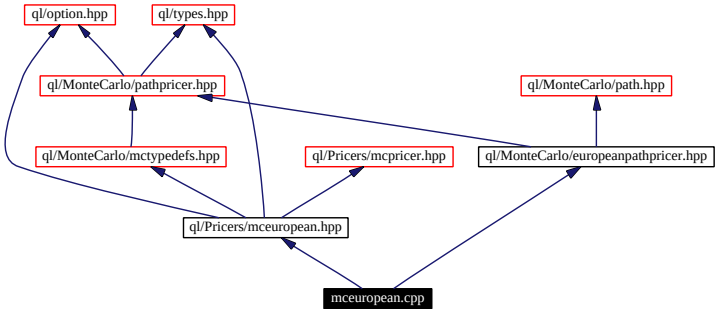
12.162 mceuropean.cpp File Reference

simple example of Monte Carlo pricer.

`#include <ql/Pricers/mceuropean.hpp>`

`#include <ql/MonteCarlo/europeanpathpricer.hpp>`

Include dependency graph for mceuropean.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.162.1 Detailed Description

Full path:
ql/Pricers/mceuropean.cpp

12.163 mceuropean.hpp File Reference

simple example of Monte Carlo pricer.

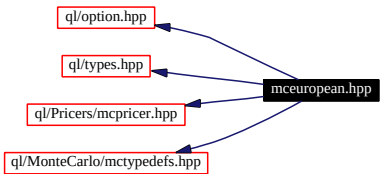
`#include <ql/option.hpp>`

`#include <ql/types.hpp>`

`#include <ql/Pricers/mcpricer.hpp>`

`#include <ql/MonteCarlo/mctypedefs.hpp>`

Include dependency graph for mceuropean.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.163.1 Detailed Description

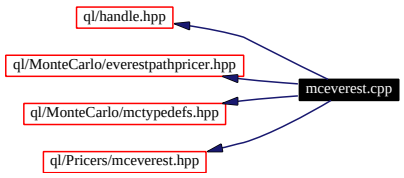
Full path:
ql/Pricers/mceuropean.hpp

12.164 mceverest.cpp File Reference

Everest-type option pricer.

```
#include <ql/handle.hpp>
#include <ql/MonteCarlo/everestpathpricer.hpp>
#include <ql/MonteCarlo/mctypedefs.hpp>
#include <ql/Pricers/mceverest.hpp>
```

Include dependency graph for mceverest.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.164.1 Detailed Description

Full path:
ql/Pricers/mceverest.cpp

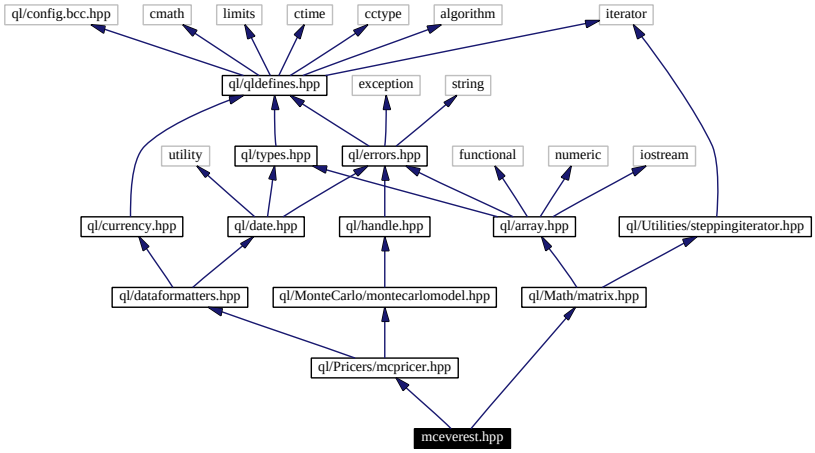
12.165 mceverest.hpp File Reference

Everest-type option pricer.

`#include <ql/Pricers/mcpricer.hpp>`

`#include <ql/Math/matrix.hpp>`

Include dependency graph for mceverest.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.165.1 Detailed Description

Full path:
ql/Pricers/mceverest.hpp

12.166 mchimalaya.cpp File Reference

Himalayan-type option pricer.

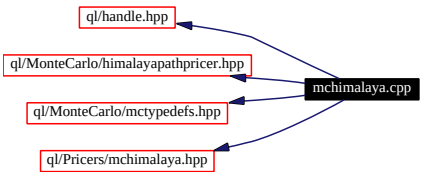
`#include <ql/handle.hpp>`

`#include <ql/MonteCarlo/himalayapathpricer.hpp>`

`#include <ql/MonteCarlo/mctypedefs.hpp>`

`#include <ql/Pricers/mchimalaya.hpp>`

Include dependency graph for mchimalaya.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.166.1 Detailed Description

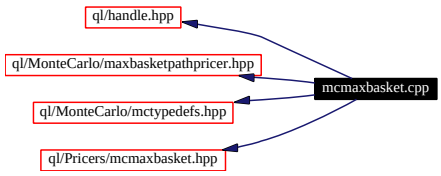
Full path:
ql/Pricers/mchimalaya.cpp

12.167 mcmaxbasket.cpp File Reference

Max Basket Monte Carlo pricer.

```
#include <ql/handle.hpp>
#include <ql/MonteCarlo/maxbasketpathpricer.hpp>
#include <ql/MonteCarlo/mctypedefs.hpp>
#include <ql/Pricers/mcmaxbasket.hpp>
```

Include dependency graph for mcmaxbasket.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.167.1 Detailed Description

Full path:
ql/Pricers/mcmaxbasket.cpp

12.168 mcpagoda.cpp File Reference

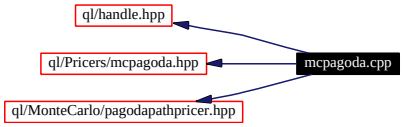
Roofed multi asset Asian option.

`#include <ql/handle.hpp>`

`#include <ql/Pricers/mcpagoda.hpp>`

`#include <ql/MonteCarlo/pagodapathpricer.hpp>`

Include dependency graph for mcpagoda.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.168.1 Detailed Description

Full path:
ql/Pricers/mcpagoda.cpp

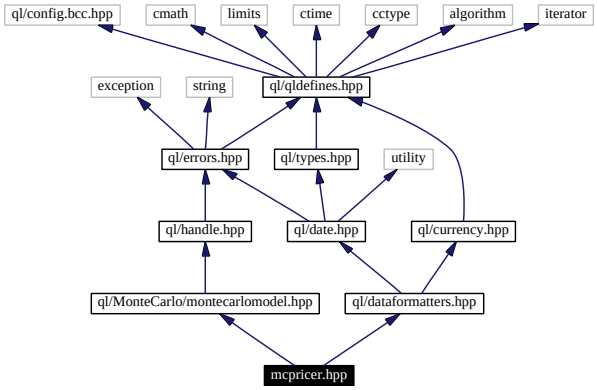
12.169 mcpricer.hpp File Reference

base class for Monte Carlo pricers.

`#include <ql/dataformatters.hpp>`

`#include <ql/MonteCarlo/montecarlomodel.hpp>`

Include dependency graph for mcpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.169.1 Detailed Description

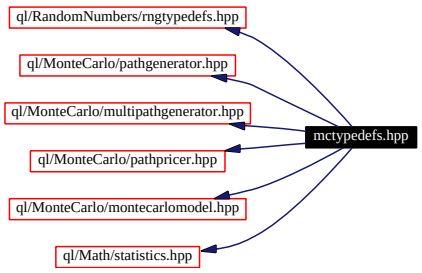
Full path:
ql/Pricers/mcpricer.hpp

12.170 mctypedefs.hpp File Reference

Default choices for template instantiations.

```
#include <ql/RandomNumbers/rngtypedefs.hpp>
#include <ql/MonteCarlo/pathgenerator.hpp>
#include <ql/MonteCarlo/multipathgenerator.hpp>
#include <ql/MonteCarlo/pathpricer.hpp>
#include <ql/MonteCarlo/montecarlomodel.hpp>
#include <ql/Math/statistics.hpp>
```

Include dependency graph for mctypedefs.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.170.1 Detailed Description

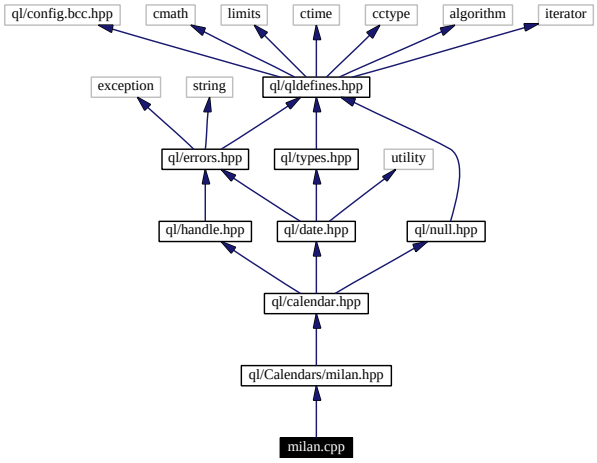
Full path:
ql/MonteCarlo/mctypedefs.hpp

12.171 milan.cpp File Reference

Milan calendar.

`#include <ql/Calendars/milan.hpp>`

Include dependency graph for milan.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.171.1 Detailed Description

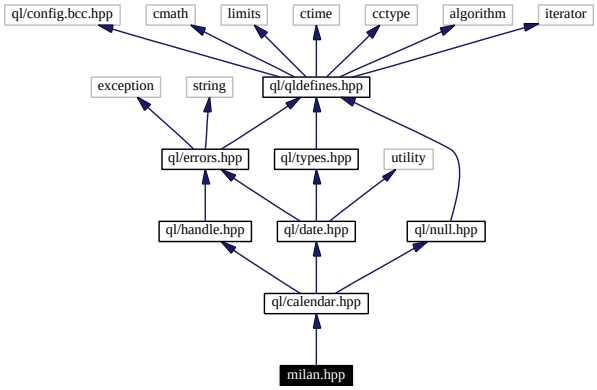
Full path:
ql/Calendars/milan.cpp

12.172 milan.hpp File Reference

Milan calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for milan.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.172.1 Detailed Description

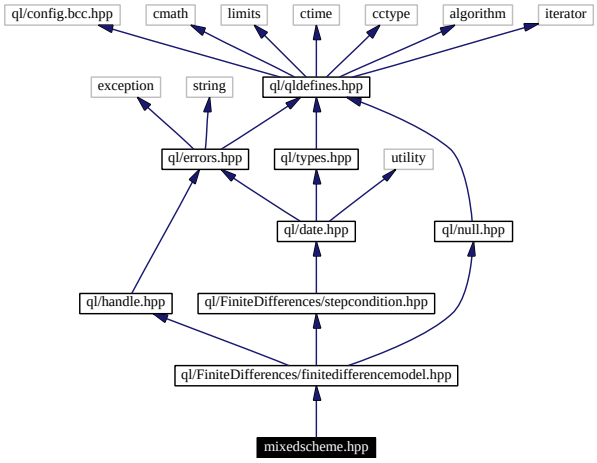
Full path:
ql/Calendars/milan.hpp

12.173 mixedscheme.hpp File Reference

Mixed (explicit/implicit) scheme for finite difference methods.

`#include <ql/FiniteDifferences/finitedifferencemodel.hpp>`

Include dependency graph for mixedscheme.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.173.1 Detailed Description

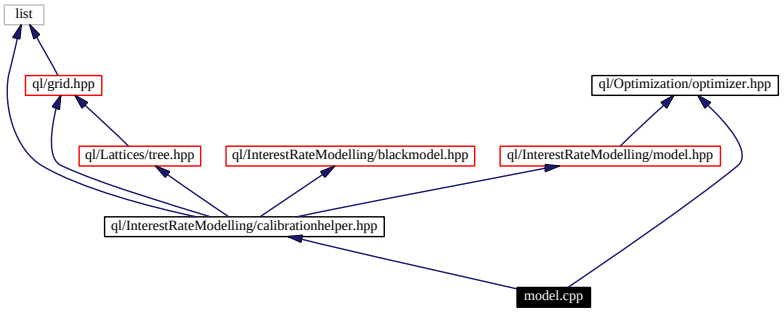
Full path:
ql/FiniteDifferences/mixedscheme.hpp

12.174 model.cpp File Reference

Abstract interest rate model class.

```
#include "ql/InterestRateModelling/calibrationhelper.hpp"
#include "ql/Optimization/optimizer.hpp"
```

Include dependency graph for model.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.174.1 Detailed Description

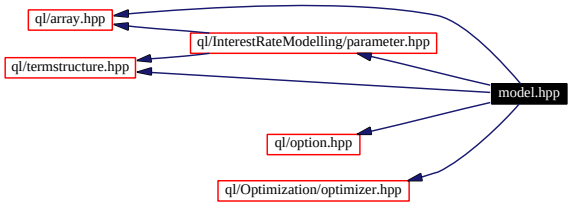
Full path:
ql/InterestRateModelling/model.cpp

12.175 model.hpp File Reference

Abstract interest rate model class.

```
#include <ql/array.hpp>
#include <ql/option.hpp>
#include <ql/termstructure.hpp>
#include <ql/InterestRateModelling/parameter.hpp>
#include <ql/Optimization/optimizer.hpp>
```

Include dependency graph for model.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.175.1 Detailed Description

Full path:
ql/InterestRateModelling/model.hpp

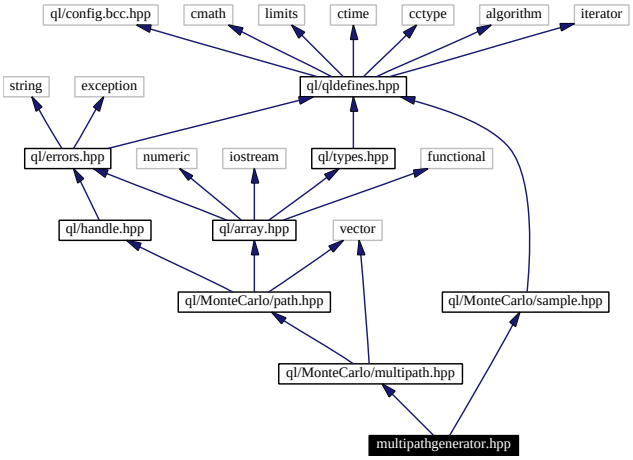
12.176 multipathgenerator.hpp File Reference

Generates a multi path from a random-array generator.

`#include <ql/MonteCarlo/multipath.hpp>`

`#include <ql/MonteCarlo/sample.hpp>`

Include dependency graph for multipathgenerator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.176.1 Detailed Description

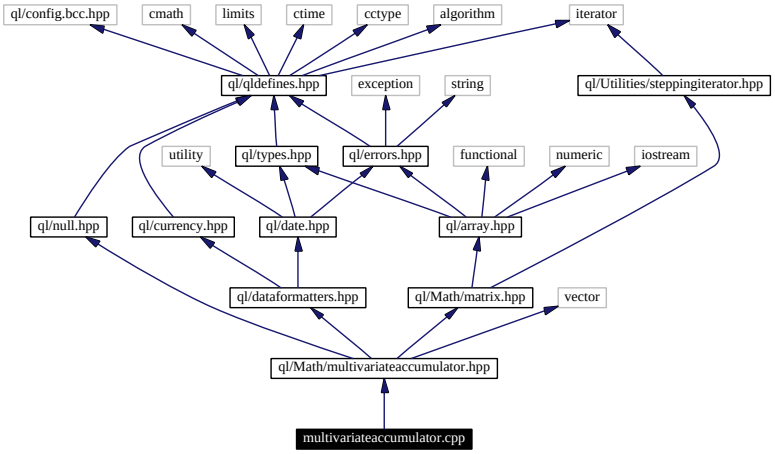
Full path:
ql/MonteCarlo/multipathgenerator.hpp

12.177 multivariateaccumulator.cpp File Reference

A simple accumulator for vector-type samples.

`#include <ql/Math/multivariateaccumulator.hpp>`

Include dependency graph for multivariateaccumulator.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.177.1 Detailed Description

Full path:
ql/Math/multivariateaccumulator.cpp

12.178 multivariateaccumulator.hpp File Reference

A simple accumulator for vector-type samples.

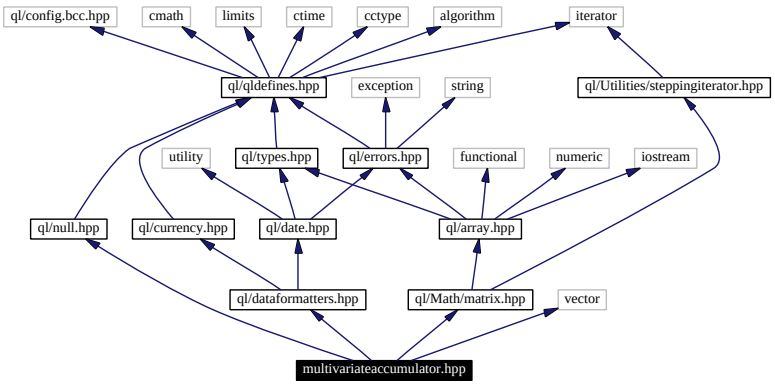
`#include <ql/null.hpp>`

`#include <ql/dataformatters.hpp>`

`#include <ql/Math/matrix.hpp>`

`#include <vector>`

Include dependency graph for multivariateaccumulator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.178.1 Detailed Description

Full path:
ql/Math/multivariateaccumulator.hpp

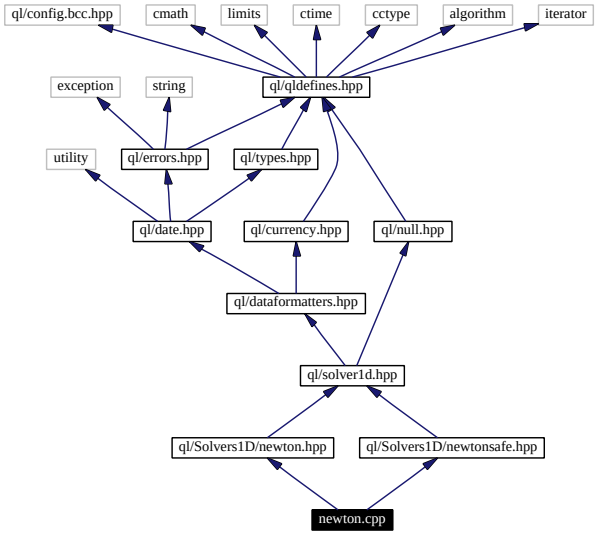
12.179 newton.cpp File Reference

Newton 1-D solver.

`#include <ql/Solvers1D/newton.hpp>`

`#include <ql/Solvers1D/newtonsafe.hpp>`

Include dependency graph for newton.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.179.1 Detailed Description

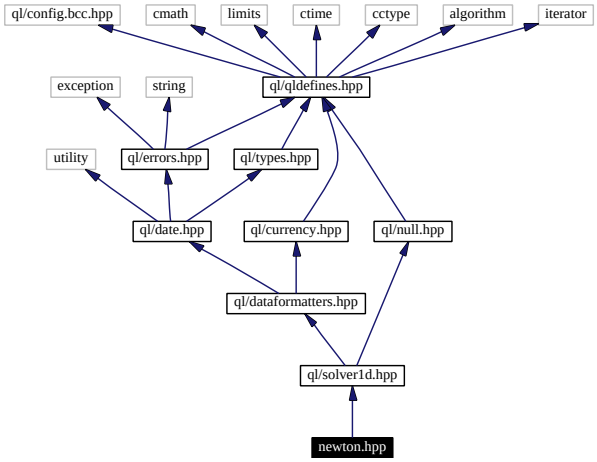
Full path:
ql/Solvers1D/newton.cpp

12.180 newton.hpp File Reference

Newton 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for newton.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.180.1 Detailed Description

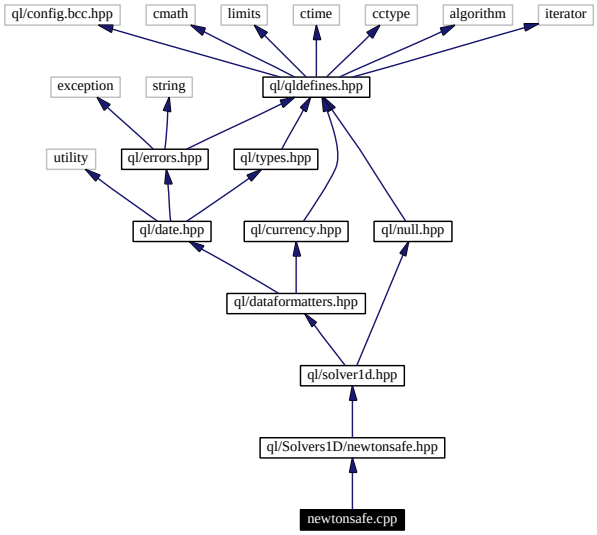
Full path:
ql/Solvers1D/newton.hpp

12.181 newtonsafe.cpp File Reference

Safe (braketed) Newton 1-D solver.

`#include <ql/Solvers1D/newtonsafe.hpp>`

Include dependency graph for newtonsafe.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.181.1 Detailed Description

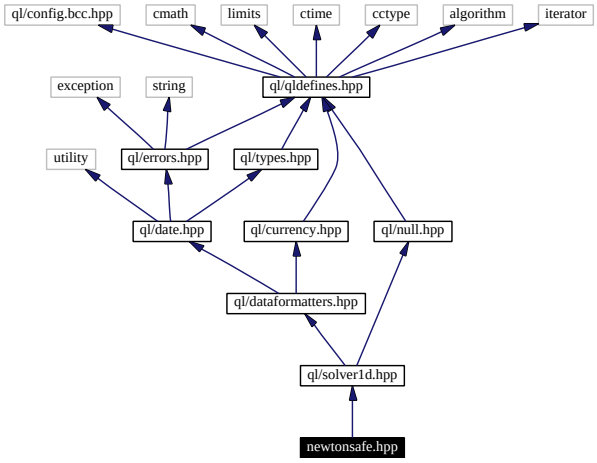
Full path:
ql/Solvers1D/newtonsafe.cpp

12.182 newtonsafe.hpp File Reference

Safe (braketed) Newton 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for newtonsafe.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.182.1 Detailed Description

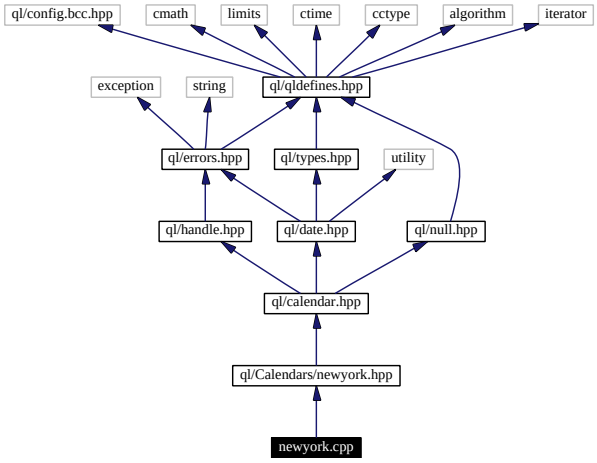
Full path:
ql/Solvers1D/newtonsafe.hpp

12.183 newyork.cpp File Reference

New York calendar.

`#include <ql/Calendars/newyork.hpp>`

Include dependency graph for newyork.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.183.1 Detailed Description

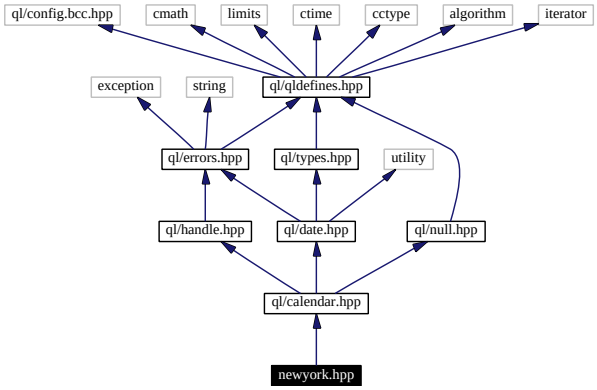
Full path:
ql/Calendars/newyork.cpp

12.184 newyork.hpp File Reference

New York calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for newyork.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.184.1 Detailed Description

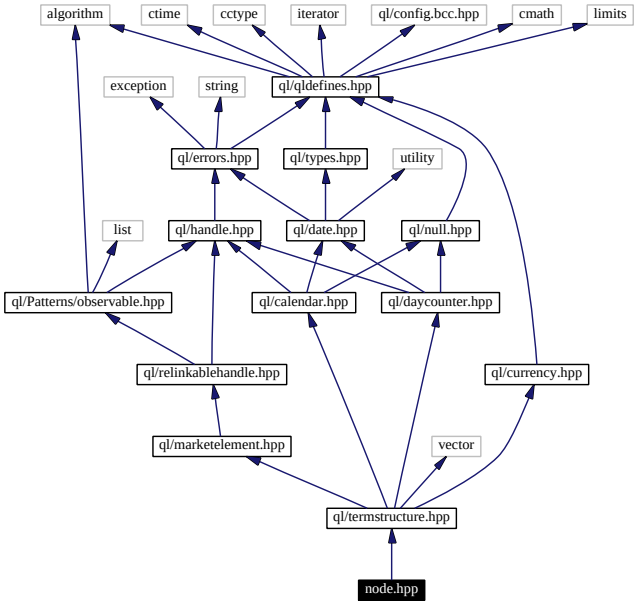
Full path:
ql/Calendars/newyork.hpp

12.185 node.hpp File Reference

Node class.

`#include <ql/termstructure.hpp>`

Include dependency graph for node.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.185.1 Detailed Description

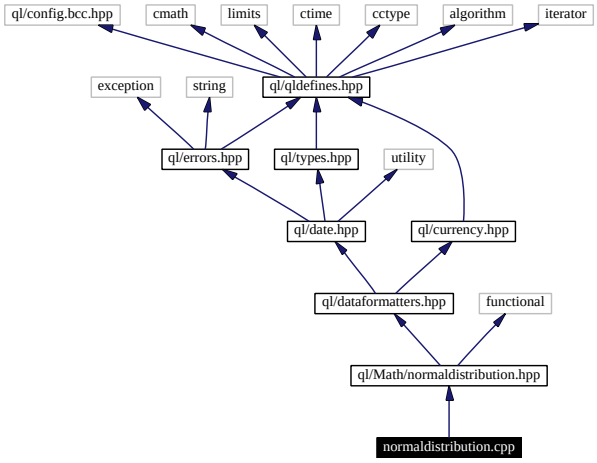
Full path:
ql/Lattices/node.hpp

12.186 normaldistribution.cpp File Reference

normal, cumulative and inverse cumulative distributions.

`#include <ql/Math/normaldistribution.hpp>`

Include dependency graph for normaldistribution.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.186.1 Detailed Description

Full path:
ql/Math/normaldistribution.cpp

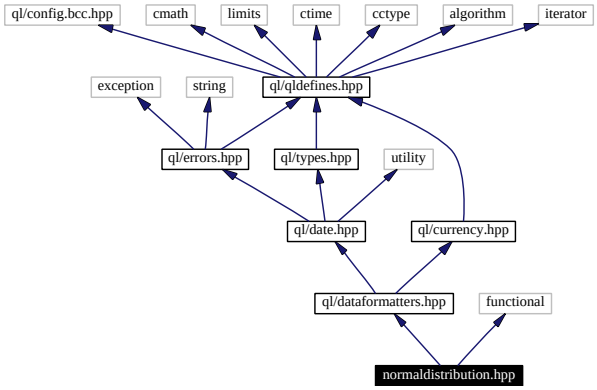
12.187 normaldistribution.hpp File Reference

normal, cumulative and inverse cumulative distributions.

`#include <ql/dataformatters.hpp>`

`#include <functional>`

Include dependency graph for normaldistribution.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.187.1 Detailed Description

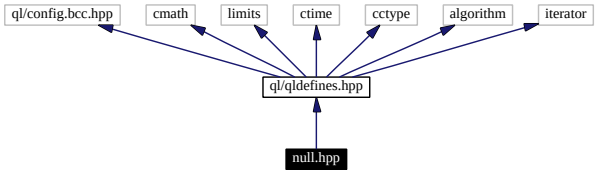
Full path:
ql/Math/normaldistribution.hpp

12.188 null.hpp File Reference

null values.

`#include <ql/qldefines.hpp>`

Include dependency graph for null.hpp:



Namespaces

- namespace QuantLib

12.188.1 Detailed Description

Full path:
ql/null.hpp

12.189 numericalmethod.hpp File Reference

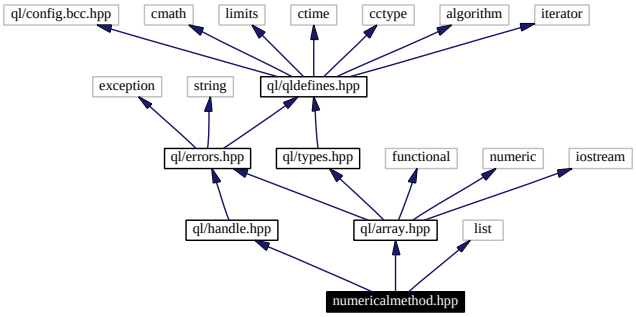
Numerical method class.

`#include <ql/array.hpp>`

`#include <ql/handle.hpp>`

`#include <list>`

Include dependency graph for numericalmethod.hpp:



Namespaces

- namespace QuantLib

12.189.1 Detailed Description

Full path:
ql/numericalmethod.hpp

12.190 observable.hpp File Reference

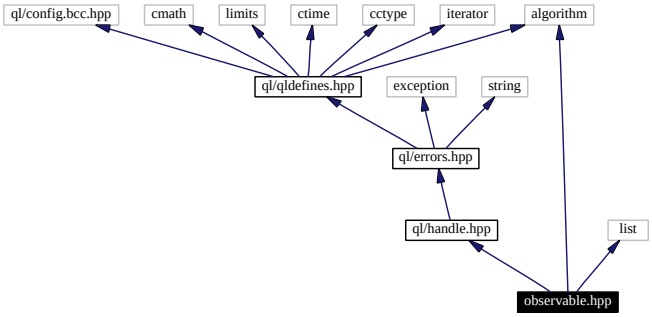
observer/observable pattern.

`#include <ql/handle.hpp>`

`#include <list>`

`#include <algorithm>`

Include dependency graph for observable.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Patterns

12.190.1 Detailed Description

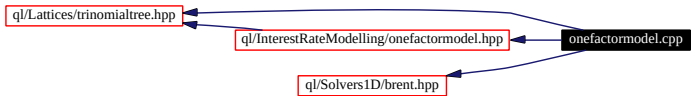
Full path:
ql/Patterns/observable.hpp

12.191 onefactormodel.cpp File Reference

Abstract one-factor interest rate model class.

```
#include "ql/InterestRateModelling/onefactormodel.hpp"
#include "ql/Lattices/trinomialtree.hpp"
#include "ql/Solvers1D/brent.hpp"
```

Include dependency graph for onefactormodel.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.191.1 Detailed Description

Full path:
ql/InterestRateModelling/onefactormodel.cpp

12.192 onefactormodel.hpp File Reference

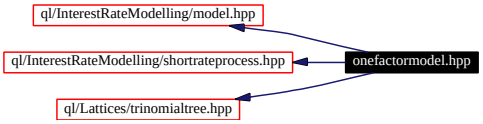
Abstract one-factor interest rate model class.

`#include <ql/InterestRateModelling/model.hpp>`

`#include <ql/InterestRateModelling/shortrateprocess.hpp>`

`#include <ql/Lattices/trinomialtree.hpp>`

Include dependency graph for onefactormodel.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.192.1 Detailed Description

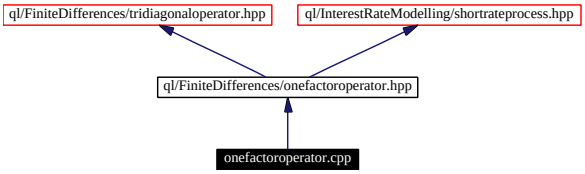
Full path:
ql/InterestRateModelling/onefactormodel.hpp

12.193 onefactoroperator.cpp File Reference

differential operator for one-factor interest rate models.

```
#include "ql/FiniteDifferences/onefactoroperator.hpp"
```

Include dependency graph for onefactoroperator.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.193.1 Detailed Description

Full path:
ql/FiniteDifferences/onefactoroperator.cpp

12.194 onefactoroperator.hpp File Reference

general differential operator for one-factor interest rate models.

`#include <ql/FiniteDifferences/tridiagonaloperator.hpp>`

`#include <ql/InterestRateModelling/shortrateprocess.hpp>`

Include dependency graph for onefactoroperator.hpp:

Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.194.1 Detailed Description

Full path:
ql/FiniteDifferences/onefactoroperator.hpp

12.195 optimizer.hpp File Reference

Abstract optimization class.

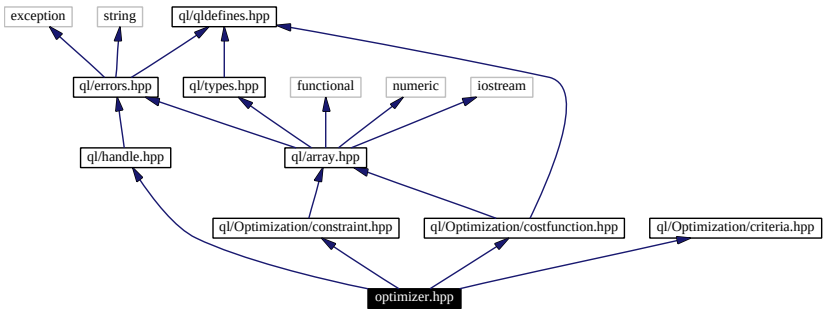
`#include <ql/handle.hpp>`

`#include <ql/Optimization/constraint.hpp>`

`#include <ql/Optimization/costfunction.hpp>`

`#include <ql/Optimization/criteria.hpp>`

Include dependency graph for optimizer.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.195.1 Detailed Description

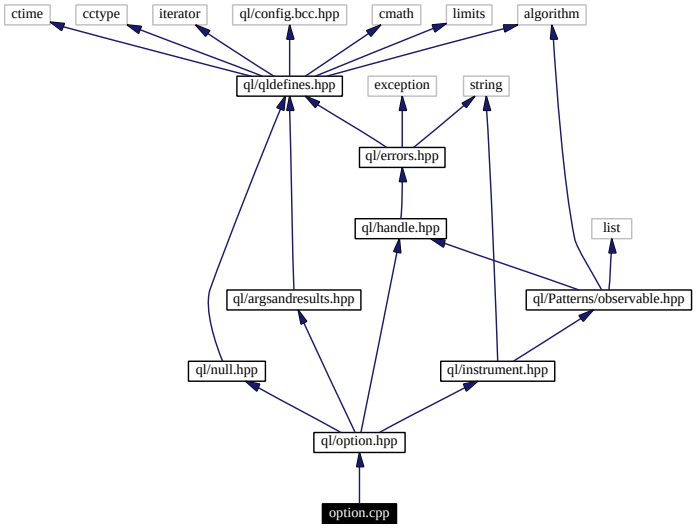
Full path:
ql/Optimization/optimizer.hpp

12.196 option.cpp File Reference

Base option class.

`#include <ql/option.hpp>`

Include dependency graph for option.cpp:



Namespaces

- namespace QuantLib

12.196.1 Detailed Description

Full path:
ql/option.cpp

12.197 option.hpp File Reference

Base option class.

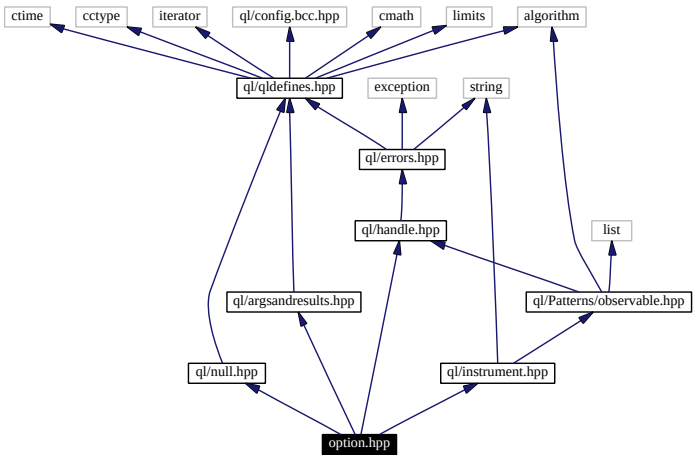
`#include <ql/instrument.hpp>`

`#include <ql/argsandresults.hpp>`

`#include <ql/handle.hpp>`

`#include <ql/null.hpp>`

Include dependency graph for option.hpp:



Namespaces

- namespace QuantLib

12.197.1 Detailed Description

Full path:
ql/option.hpp

12.198 pagodapathpricer.cpp File Reference

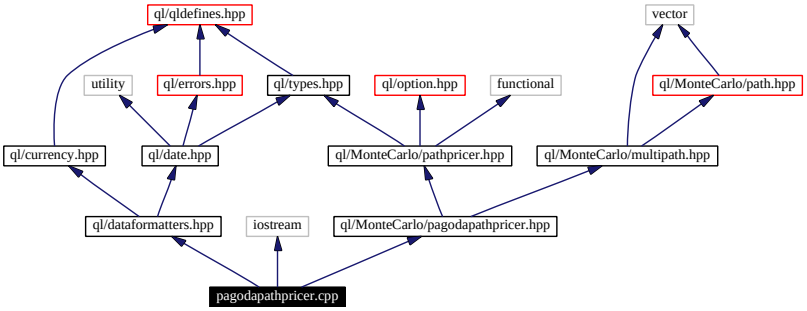
path pricer for pagoda options.

`#include <ql/MonteCarlo/pagodapathpricer.hpp>`

`#include <ql/dataformatters.hpp>`

`#include <iostream>`

Include dependency graph for pagodapathpricer.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.198.1 Detailed Description

Full path:
MonteCarlo/pagodapathpricer.cpp

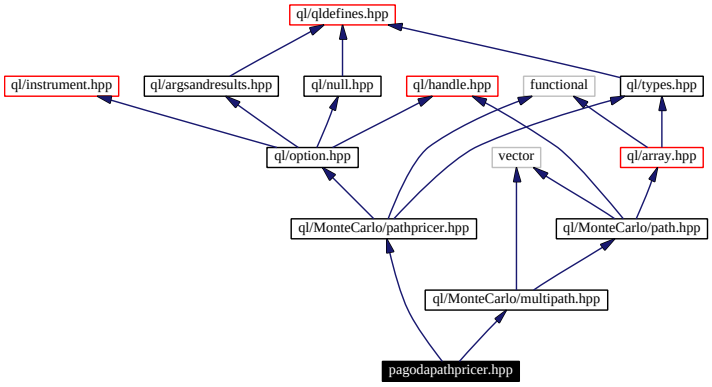
12.199 pagodapathpricer.hpp File Reference

path pricer for pagoda options.

`#include <ql/MonteCarlo/pathpricer.hpp>`

`#include <ql/MonteCarlo/multipath.hpp>`

Include dependency graph for pagodapathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.199.1 Detailed Description

Full path:
ql/MonteCarlo/pagodapathpricer.hpp

12.200 parameter.hpp File Reference

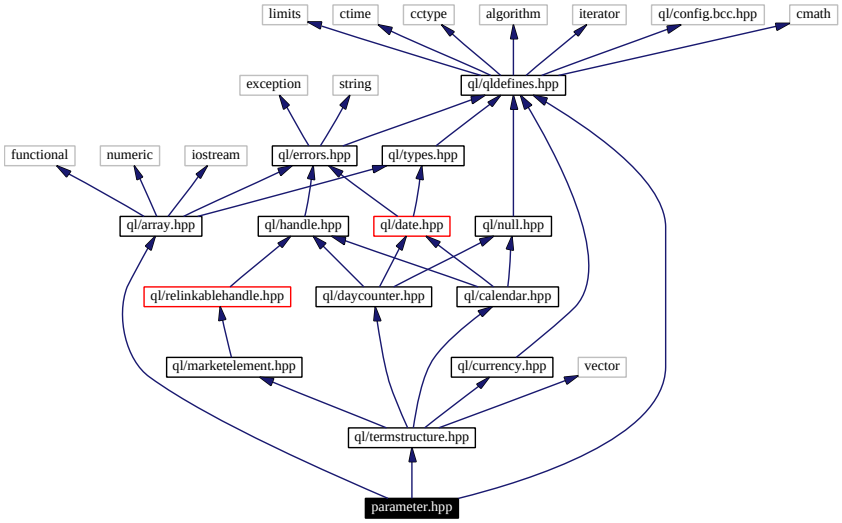
Model parameter classes.

`#include <ql/qldefines.hpp>`

`#include <ql/array.hpp>`

`#include <ql/termstructure.hpp>`

Include dependency graph for parameter.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.200.1 Detailed Description

Full path:
ql/InterestRateModelling/parameter.hpp

12.201 pathpricer.hpp File Reference

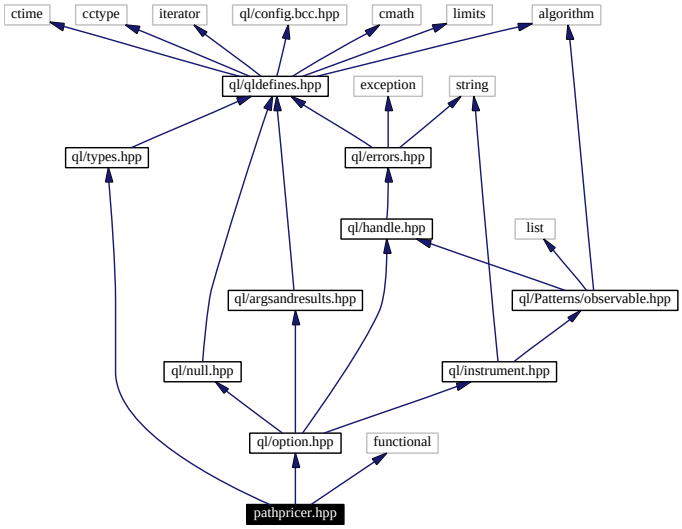
base class for single-path pricers.

`#include <ql/option.hpp>`

`#include <ql/types.hpp>`

`#include <functional>`

Include dependency graph for pathpricer.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.201.1 Detailed Description

Full path:
ql/MonteCarlo/pathpricer.hpp

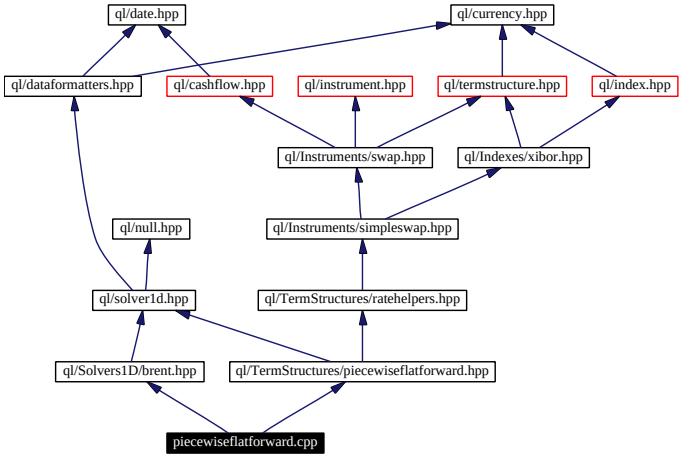
12.202 piecewiseflatforward.cpp File Reference

piecewise flat forward term structure.

`#include <ql/TermStructures/piecewiseflatforward.hpp>`

`#include <ql/Solvers1D/brent.hpp>`

Include dependency graph for piecewiseflatforward.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::TermStructures

12.202.1 Detailed Description

Full path:
ql/TermStructures/piecewiseflatforward.cpp

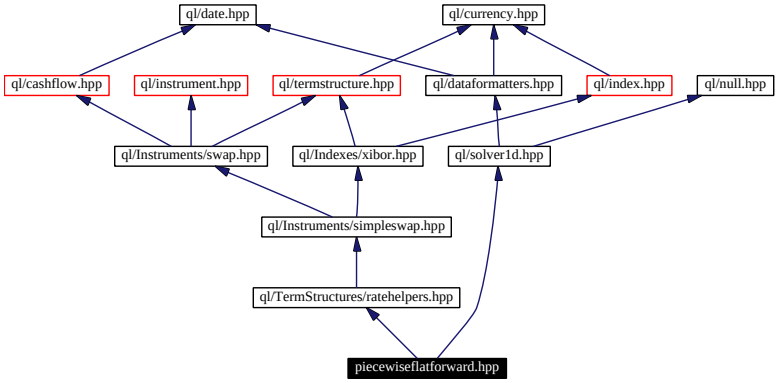
12.203 piecewiseflatforward.hpp File Reference

piecewise flat forward term structure.

`#include <ql/TermStructures/ratehelpers.hpp>`

`#include <ql/solver1d.hpp>`

Include dependency graph for piecewiseflatforward.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::TermStructures

12.203.1 Detailed Description

Full path:
ql/TermStructures/piecewiseflatforward.hpp

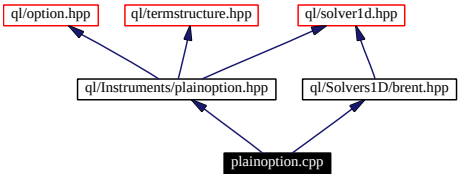
12.204 plainoption.cpp File Reference

Plain (no dividends, no barriers) option on a single asset.

`#include <ql/Instruments/plainoption.hpp>`

`#include <ql/Solvers1D/brent.hpp>`

Include dependency graph for plainoption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments
- namespace QuantLib::Pricers

12.204.1 Detailed Description

Full path:
ql/Instruments/plainoption.cpp

12.205 plainoption.hpp File Reference

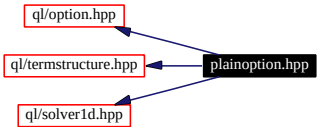
Plain (no dividends, no barriers) option on a single asset.

`#include <ql/option.hpp>`

`#include <ql/termstructure.hpp>`

`#include <ql/solver1d.hpp>`

Include dependency graph for plainoption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments
- namespace QuantLib::Pricers

12.205.1 Detailed Description

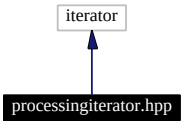
Full path:
ql/Instruments/plainoption.hpp

12.206 processingiterator.hpp File Reference

Iterator mapping a unary function to an underlying sequence.

`#include <iterator>`

Include dependency graph for processingiterator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.206.1 Detailed Description

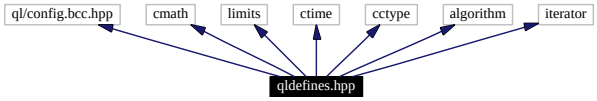
Full path:
ql/Utilities/processingiterator.hpp

12.207 qldefines.hpp File Reference

Global definitions and compiler switches.

```
#include <ql/config.bcc.hpp>
#include <cmath>
#include <limits>
#include <ctime>
#include <cctype>
#include <algorithm>
#include <iterator>
```

Include dependency graph for qldefines.hpp:



Namespaces

- namespace QuantLib

Defines

- #define QL_HEX_VERSION 0x000300b1

  version hexadecimal number.

- #define QL_VERSION "0.3.0b1-20020322"

  version string.

- #define QL_TRACE_LEVEL 0

  global trace level (may be superseded locally by a greater value).

- #define QL_DUMMY_RETURN(x)

  Is a dummy return statement required?

- #define QL_MIN_INT ((std::numeric_limits<int>::min)())
- #define QL_MAX_INT ((std::numeric_limits<int>::max)())
- #define QL_MIN_DOUBLE -((std::numeric_limits<double>::max)())
- #define QL_MAX_DOUBLE ((std::numeric_limits<double>::max)())
- #define QL_EPSILON ((std::numeric_limits<double>::epsilon)())
- #define **QL_MIN_POSITIVE_DOUBLE** ((std::numeric_limits<double>::min)())
- #define QL_DECLARE_TEMPLATE_SPECIALIZATIONS

  Blame Microsoft for this one...

- #define QL_ALLOW_TEMPLATE_METHOD_CALLS 1

  Blame Microsoft for this one...

- #define QL_EXPRESSION_TEMPLATES_WORK 1
- #define QL_TEMPLATE_METAPROGRAMMING_WORKS 1
- #define QL_SPECIALIZE_ITERATOR_TRAITS(T)
- #define QL_REVERSE_ITERATOR(iterator, type) std::reverse_iterator< iterator >

  Blame Microsoft for this one...

- #define **QL_FULL_ITERATOR_SUPPORT**

12.207.1 Detailed Description

Full path:
ql/qldefines.hpp

12.208 randomarraygenerator.hpp File Reference

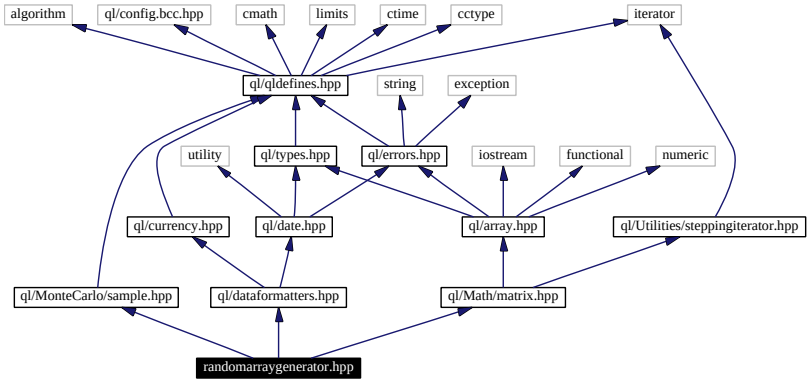
Generates random arrays from a random number generator.

`#include <ql/Math/matrix.hpp>`

`#include <ql/MonteCarlo/sample.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for randomarraygenerator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.208.1 Detailed Description

Full path:
ql/RandomNumbers/randomarraygenerator.hpp

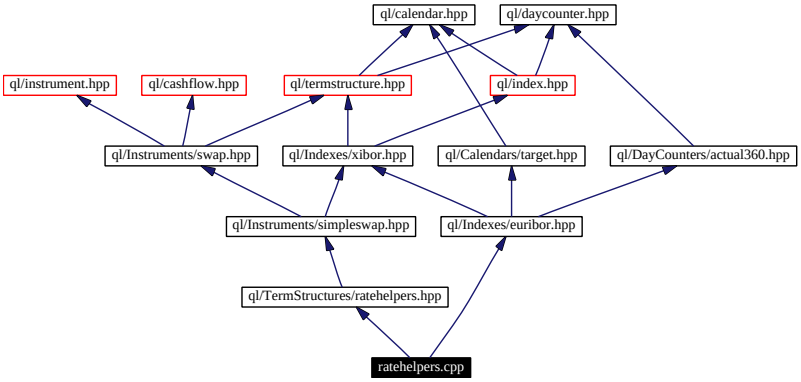
12.209 ratehelpers.cpp File Reference

rate helpers base class.

`#include <ql/TermStructures/ratehelpers.hpp>`

`#include <ql/Indexes/euribor.hpp>`

Include dependency graph for ratehelpers.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::TermStructures

12.209.1 Detailed Description

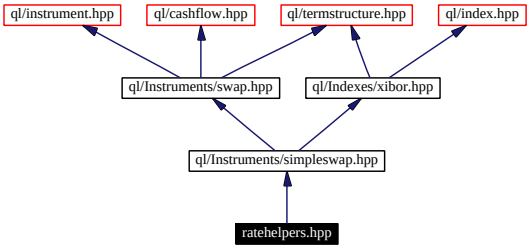
Full path:
ql/TermStructures/ratehelpers.cpp

12.210 ratehelpers.hpp File Reference

rate helpers base class.

`#include <ql/Instruments/simpleswap.hpp>`

Include dependency graph for ratehelpers.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::TermStructures

12.210.1 Detailed Description

Full path:
ql/TermStructures/ratehelpers.hpp

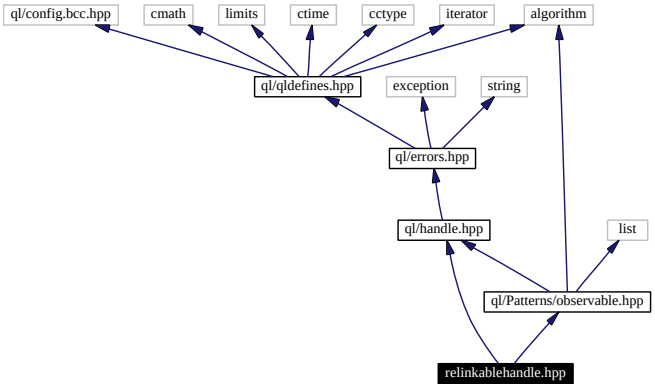
12.211 relinkablehandle.hpp File Reference

Globally accessible relinkable pointer.

`#include <ql/handle.hpp>`

`#include <ql/Patterns/observable.hpp>`

Include dependency graph for relinkablehandle.hpp:



Namespaces

- namespace QuantLib

12.211.1 Detailed Description

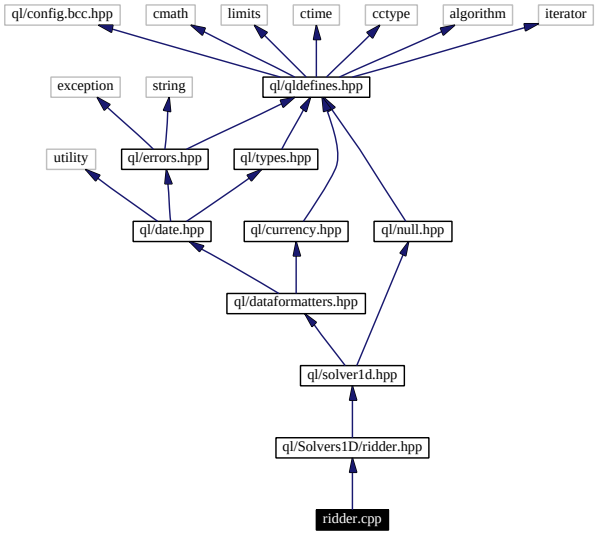
Full path:
ql/relinkablehandle.hpp

12.212 ridder.cpp File Reference

Ridder 1-D solver.

`#include <ql/Solvers1D/ridder.hpp>`

Include dependency graph for ridder.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

Defines

- #define **SIGN**(a, b) ((b) >= 0.0 ? QL_FABS(a) : -QL_FABS(a))

12.212.1 Detailed Description

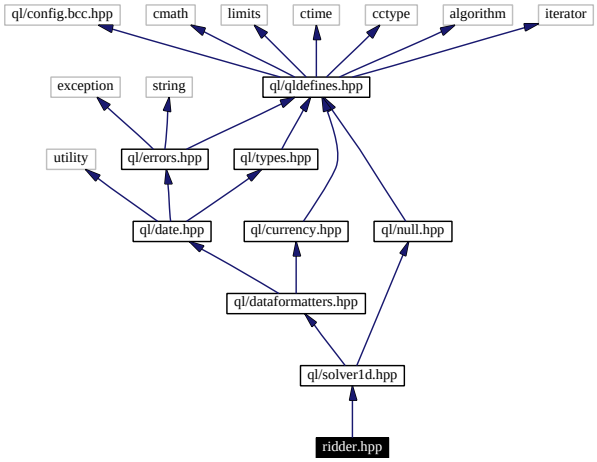
Full path:
ql/Solvers1D/ridder.cpp

12.213 ridder.hpp File Reference

Ridder 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for ridder.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.213.1 Detailed Description

Full path:
ql/Solvers1D/ridder.hpp

12.214 riskmeasures.hpp File Reference

Risk functions.

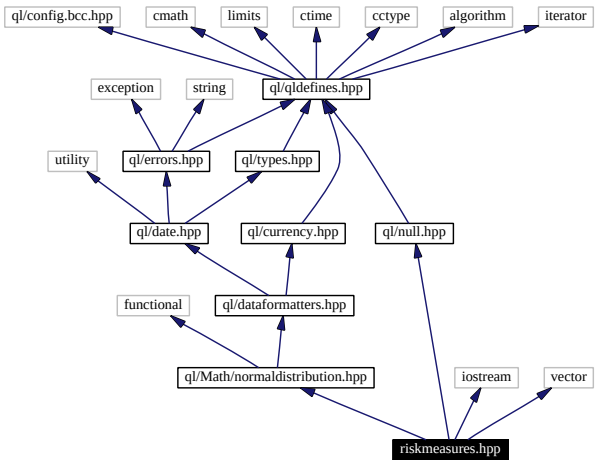
`#include <ql/null.hpp>`

`#include <ql/Math/normaldistribution.hpp>`

`#include <iostream>`

`#include <vector>`

Include dependency graph for riskmeasures.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.214.1 Detailed Description

Full path:
ql/Math/riskmeasures.hpp

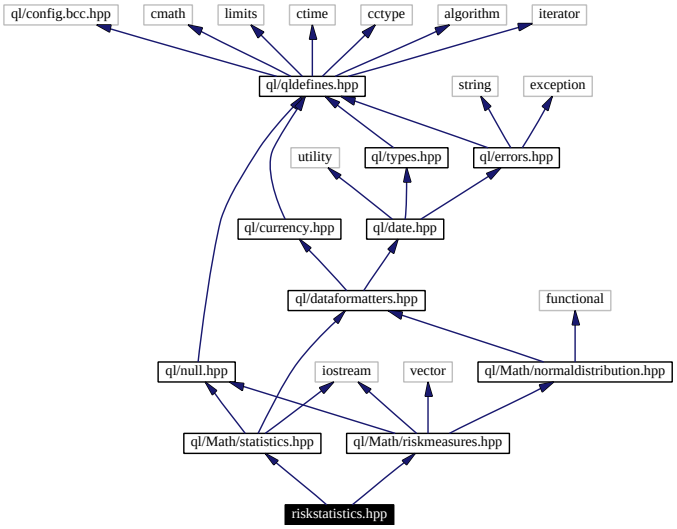
12.215 riskstatistics.hpp File Reference

Normal distribution risk analysis tool: VAR, (average) shortfall.

`#include <ql/Math/statistics.hpp>`

`#include <ql/Math/riskmeasures.hpp>`

Include dependency graph for riskstatistics.hpp:



Namespaces

- namespace QuantLib

12.215.1 Detailed Description

Full path:

ql/riskstatistics.hpp

12.216 rngtypedefs.hpp File Reference

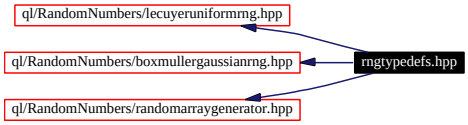
Default choices for template instantiations.

`#include <ql/RandomNumbers/lecuyeruniformrng.hpp>`

`#include <ql/RandomNumbers/boxmullergaussianrng.hpp>`

`#include <ql/RandomNumbers/randomarraygenerator.hpp>`

Include dependency graph for rngtypedefs.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::RandomNumbers

12.216.1 Detailed Description

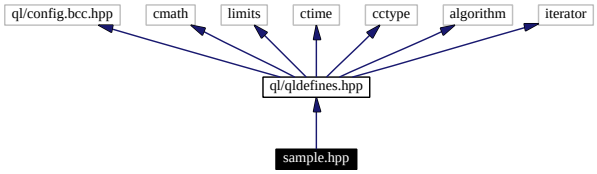
Full path:
ql/RandomNumbers/rngtypedefs.hpp

12.217 sample.hpp File Reference

weighted sample.

`#include <ql/qldefines.hpp>`

Include dependency graph for sample.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::MonteCarlo

12.217.1 Detailed Description

Full path:
ql/MonteCarlo/sample.hpp

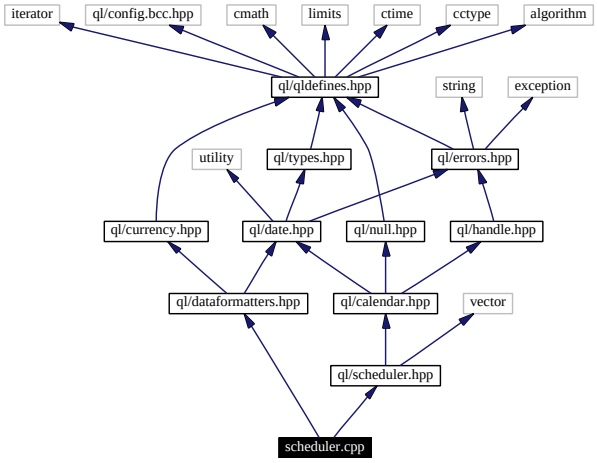
12.218 scheduler.cpp File Reference

date scheduler.

`#include <ql/scheduler.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for scheduler.cpp:



Namespaces

- namespace QuantLib

12.218.1 Detailed Description

Full path:
ql/scheduler.cpp

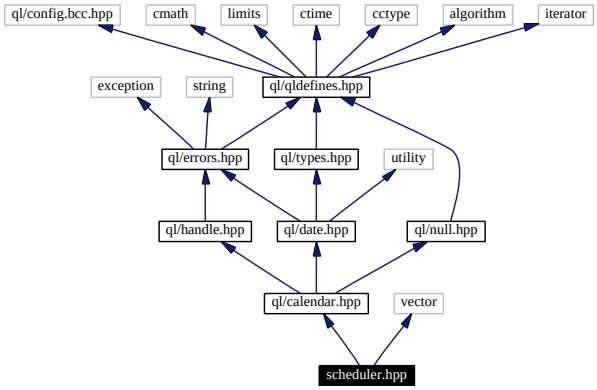
12.219 scheduler.hpp File Reference

date scheduler.

`#include <ql/calendar.hpp>`

`#include <vector>`

Include dependency graph for scheduler.hpp:



Namespaces

- namespace QuantLib

12.219.1 Detailed Description

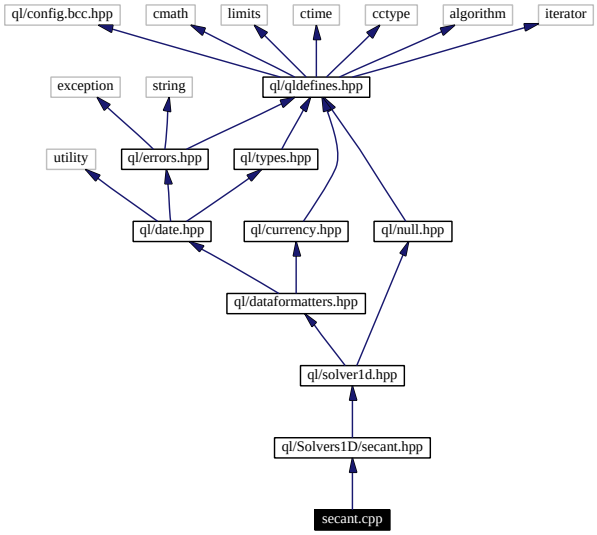
Full path:
ql/scheduler.hpp

12.220 secant.cpp File Reference

secant 1-D solver.

`#include <ql/Solvers1D/secant.hpp>`

Include dependency graph for secant.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.220.1 Detailed Description

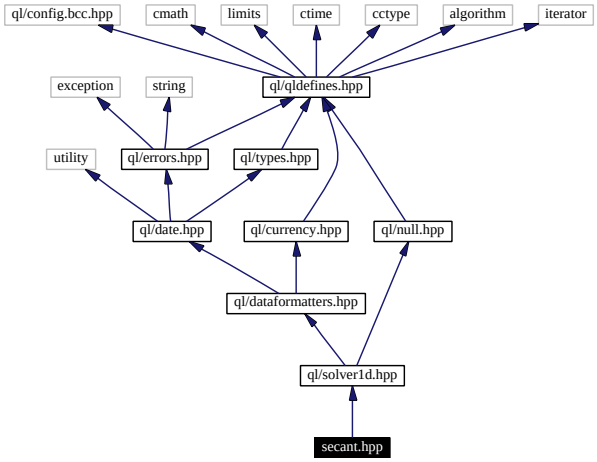
Full path:
ql/Solvers1D/secant.cpp

12.221 secant.hpp File Reference

secant 1-D solver.

`#include <ql/solver1d.hpp>`

Include dependency graph for secant.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

12.221.1 Detailed Description

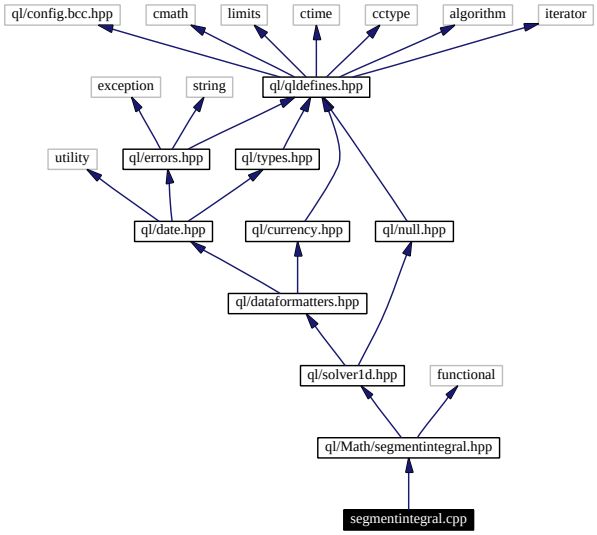
Full path:
ql/Solvers1D/secant.hpp

12.222 segmentintegral.cpp File Reference

Integral of a function over a segment.

`#include <ql/Math/segmentintegral.hpp>`

Include dependency graph for segmentintegral.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.222.1 Detailed Description

Full path:
ql/Math/segmentintegral.cpp

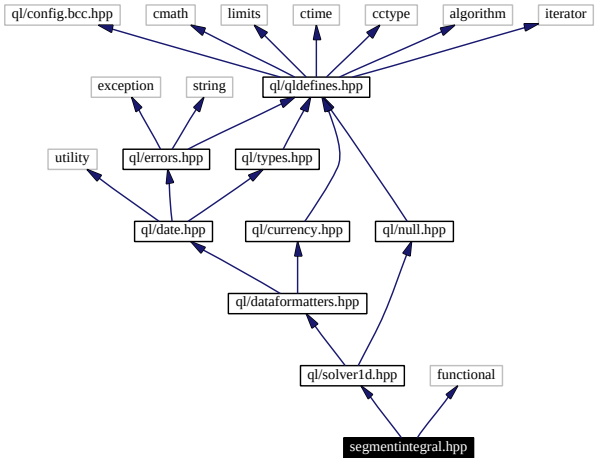
12.223 segmentintegral.hpp File Reference

Integral of a one-dimensional function.

`#include <ql/solver1d.hpp>`

`#include <functional>`

Include dependency graph for segmentintegral.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.223.1 Detailed Description

Full path:
ql/Math/integral.hpp

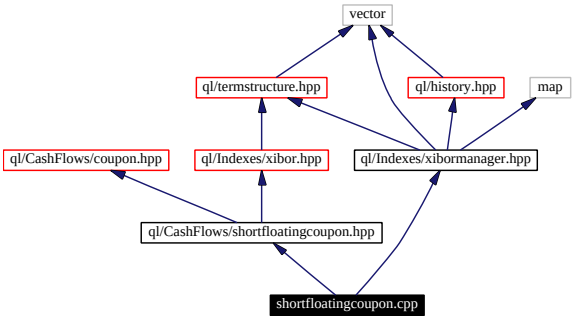
12.224 shortfloatingcoupon.cpp File Reference

Short coupon at par on a term structure.

`#include <ql/CashFlows/shortfloatingcoupon.hpp>`

`#include <ql/Indexes/xibormanager.hpp>`

Include dependency graph for shortfloatingcoupon.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.224.1 Detailed Description

Full path:
ql/CashFlows/shortfloatingcoupon.cpp

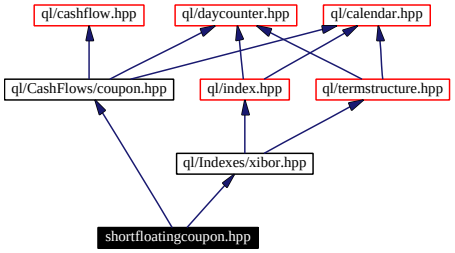
12.225 shortfloatingcoupon.hpp File Reference

Short (or long) coupon at par on a term structure.

`#include <ql/CashFlows/coupon.hpp>`

`#include <ql/Indexes/xibor.hpp>`

Include dependency graph for shortfloatingcoupon.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.225.1 Detailed Description

Full path:
ql/CashFlows/shortfloatingcoupon.hpp

12.226 shortrateprocess.hpp File Reference

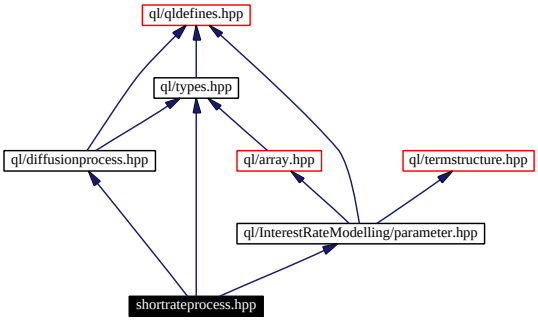
Short rate process.

`#include <ql/diffusionprocess.hpp>`

`#include <ql/types.hpp>`

`#include <ql/InterestRateModelling/parameter.hpp>`

Include dependency graph for shortrateprocess.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.226.1 Detailed Description

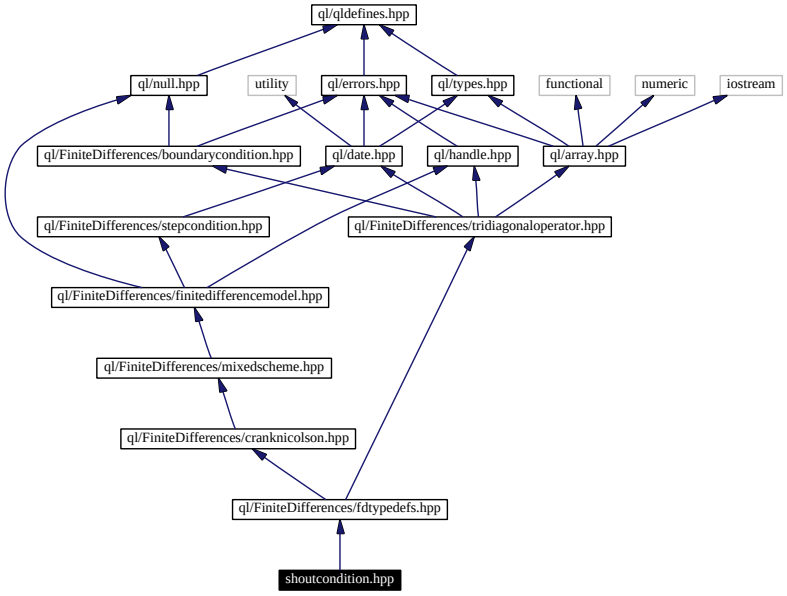
Full path:
ql/InterestRateModelling/shortrateprocess.hpp

12.227 shoutcondition.hpp File Reference

shout option exercise condition.

`#include <ql/FiniteDifferences/fdtypedefs.hpp>`

Include dependency graph for shoutcondition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.227.1 Detailed Description

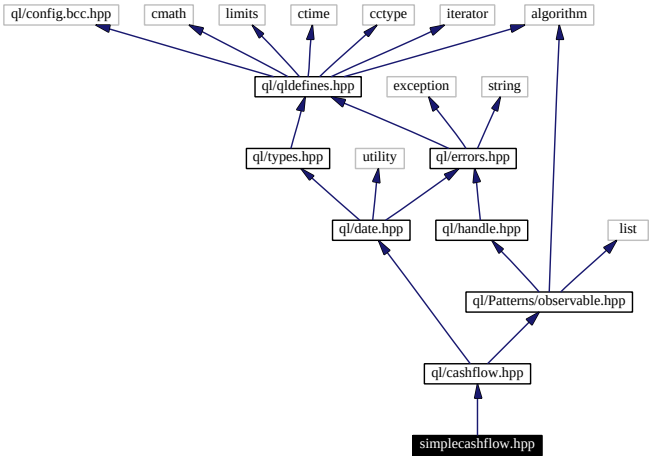
Full path:
ql/FiniteDifferences/shoutcondition.hpp

12.228 simplecashflow.hpp File Reference

Predetermined cash flow.

`#include <ql/cashflow.hpp>`

Include dependency graph for simplecashflow.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::CashFlows

12.228.1 Detailed Description

Full path:
ql/CashFlows/simplecashflow.hpp

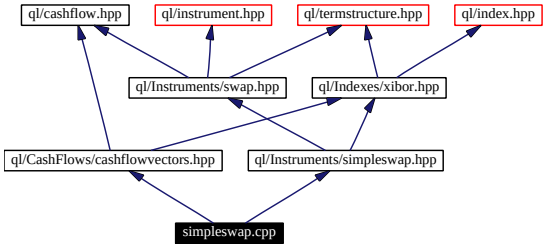
12.229 simpleswap.cpp File Reference

Simple fixed-rate vs Libor swap.

`#include <ql/Instruments/simpleswap.hpp>`

`#include <ql/CashFlows/cashflowvectors.hpp>`

Include dependency graph for simpleswap.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.229.1 Detailed Description

Full path:
ql/Instruments/simpleswap.cpp

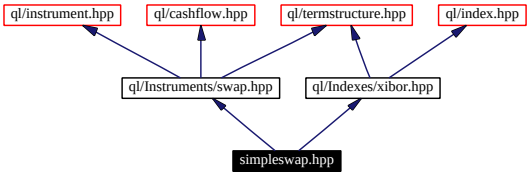
12.230 simpleswap.hpp File Reference

Simple fixed-rate vs Libor swap.

`#include <ql/Instruments/swap.hpp>`

`#include <ql/Indexes/xibor.hpp>`

Include dependency graph for simpleswap.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.230.1 Detailed Description

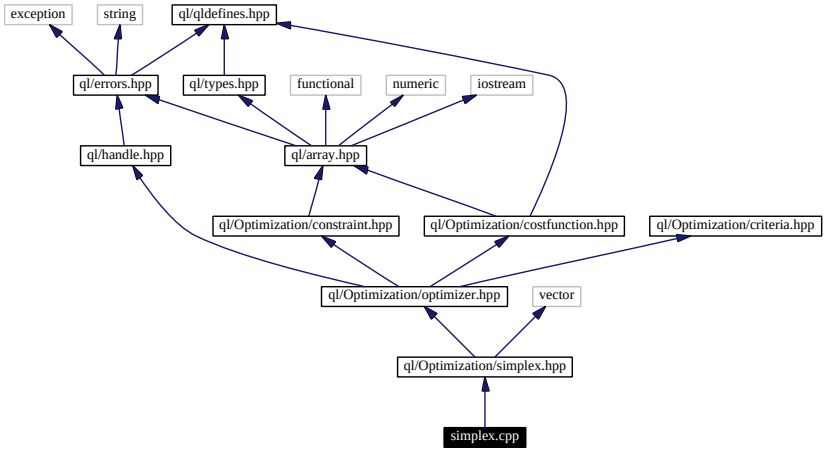
Full path:
ql/Instruments/simpleswap.hpp

12.231 simplex.cpp File Reference

Simplex optimization method.

`#include "ql/Optimization/simplex.hpp"`

Include dependency graph for simplex.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.231.1 Detailed Description

Full path:
ql/Optimization/simplex.cpp

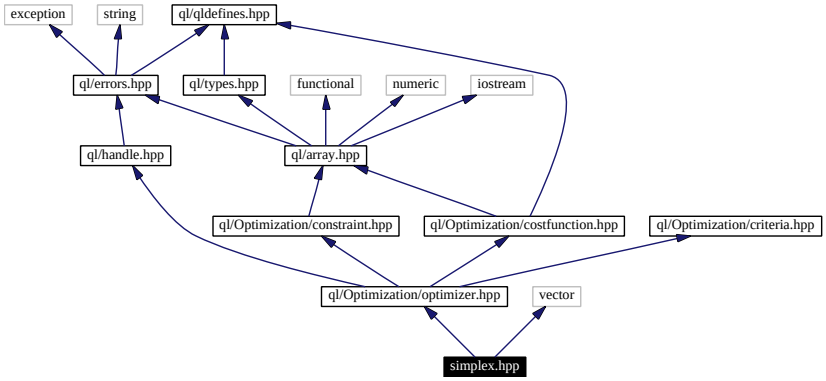
12.232 simplex.hpp File Reference

Simplex optimization method.

`#include <ql/Optimization/optimizer.hpp>`

`#include <vector>`

Include dependency graph for simplex.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.232.1 Detailed Description

Full path:
ql/Optimization/simplex.hpp

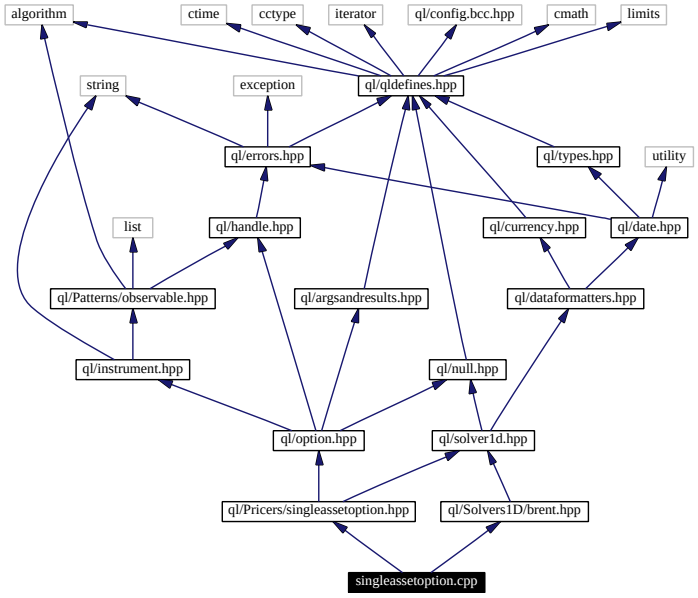
12.233 singleassetoption.cpp File Reference

common code for option evaluation.

`#include <ql/Pricers/singleassetoption.hpp>`

`#include <ql/Solvers1D/brent.hpp>`

Include dependency graph for singleassetoption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.233.1 Detailed Description

Full path:
ql/Pricers/singleassetoption.cpp

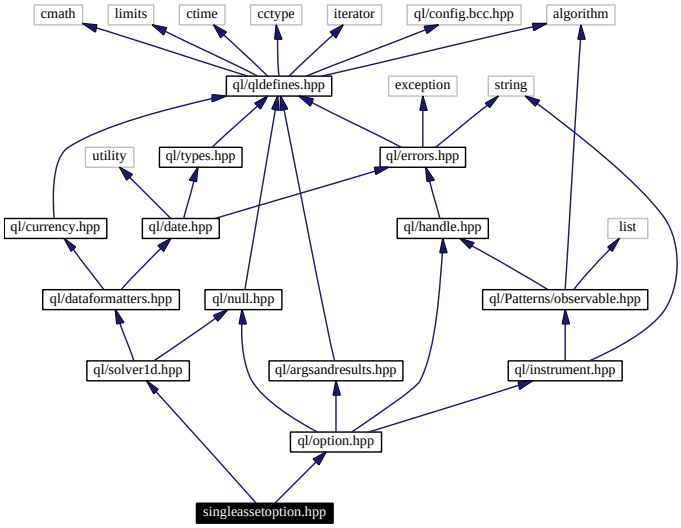
12.234 singleassetoption.hpp File Reference

common code for option evaluation.

`#include <ql/option.hpp>`

`#include <ql/solver1d.hpp>`

Include dependency graph for singleassetoption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

Defines

- #define **QL_MIN_VOLATILITY** 0.0001
- #define **QL_MAX_VOLATILITY** 4.0

12.234.1 Detailed Description

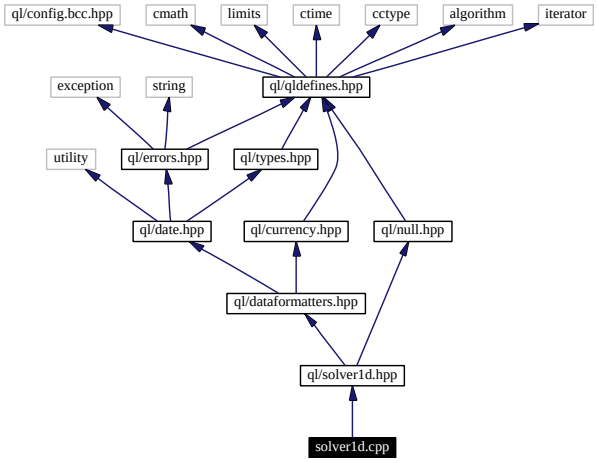
Full path:
ql/Pricers/singleassetoption.hpp

12.235 solver1d.cpp File Reference

Abstract 1-D solver class.

`#include <ql/solver1d.hpp>`

Include dependency graph for solver1d.cpp:



Namespaces

- namespace QuantLib

12.235.1 Detailed Description

Full path:
ql/solver1d.cpp

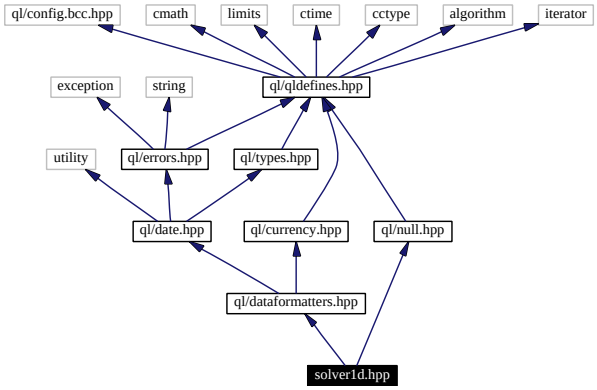
12.236 solver1d.hpp File Reference

Abstract 1-D solver class.

`#include <ql/null.hpp>`

`#include <ql/dataformatters.hpp>`

Include dependency graph for solver1d.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Solvers1D

Defines

- #define **MAX_FUNCTION_EVALUATIONS** 100

12.236.1 Detailed Description

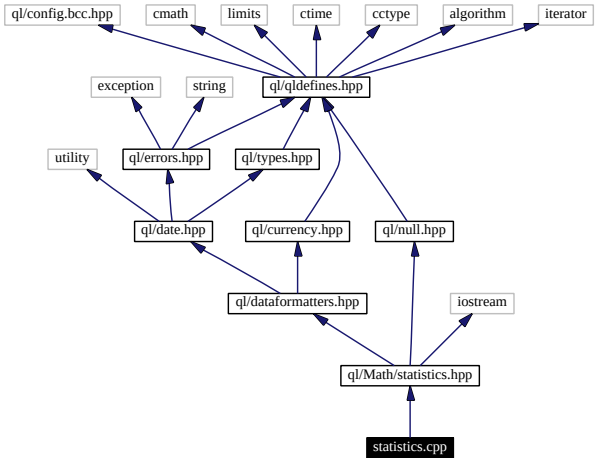
Full path:
ql/solver1d.hpp

12.237 statistics.cpp File Reference

statistic tools.

`#include <ql/Math/statistics.hpp>`

Include dependency graph for statistics.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.237.1 Detailed Description

Full path:
ql/Math/statistics.cpp

12.238 statistics.hpp File Reference

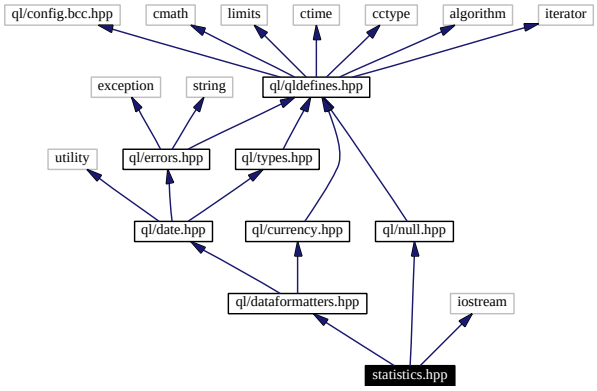
statistic tools.

`#include <ql/null.hpp>`

`#include <ql/dataformatters.hpp>`

`#include <iostream>`

Include dependency graph for statistics.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.238.1 Detailed Description

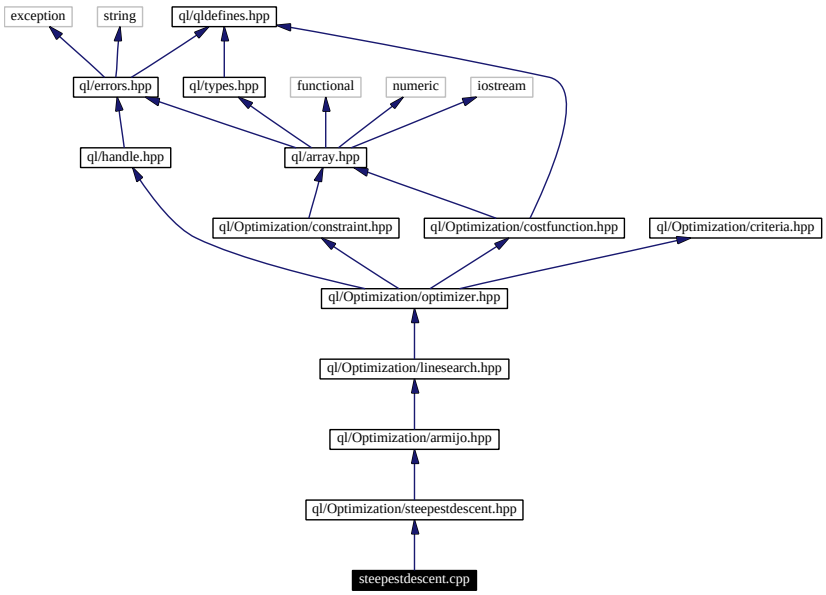
Full path:
ql/Math/statistics.hpp

12.239 steepestdescent.cpp File Reference

Steepest descent optimization method.

`#include "ql/Optimization/steepestdescent.hpp"`

Include dependency graph for steepestdescent.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.239.1 Detailed Description

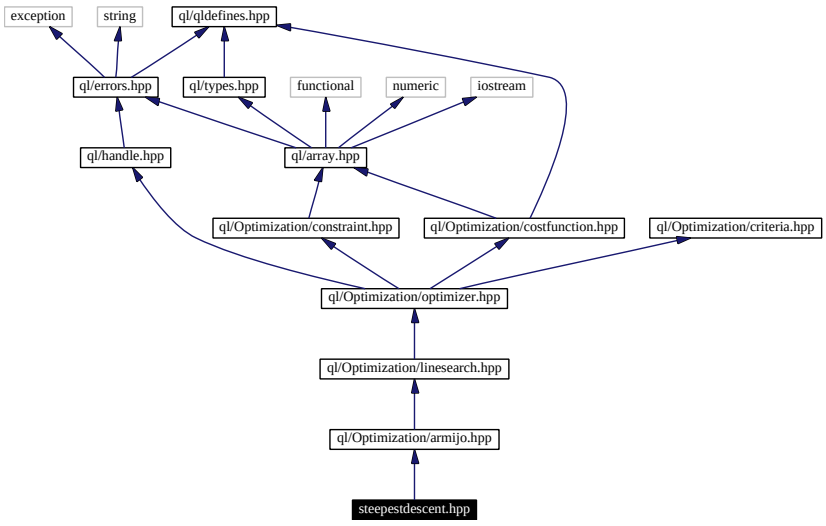
Full path:
ql/Optimization/steepestdescent.cpp

12.240 steepestdescent.hpp File Reference

Steepest descent optimization method.

`#include <ql/Optimization/armijo.hpp>`

Include dependency graph for steepestdescent.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Optimization**

12.240.1 Detailed Description

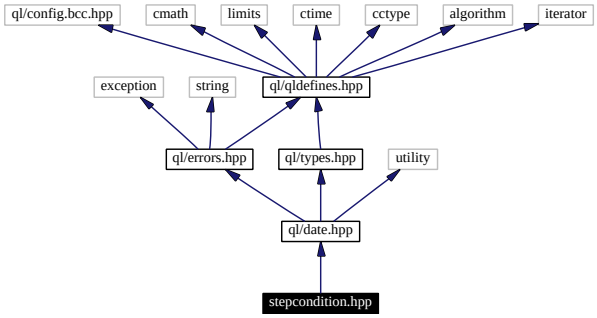
Full path:
ql/Optimization/steepestdescent.hpp

12.241 stepcondition.hpp File Reference

conditions to be applied at every time step.

`#include <ql/date.hpp>`

Include dependency graph for stepcondition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.241.1 Detailed Description

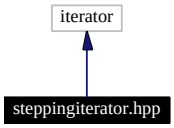
Full path:
ql/FiniteDifferences/stepcondition.hpp

12.242 steppingiterator.hpp File Reference

Iterator advancing in constant steps.

`#include <iterator>`

Include dependency graph for steppingiterator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Utilities

12.242.1 Detailed Description

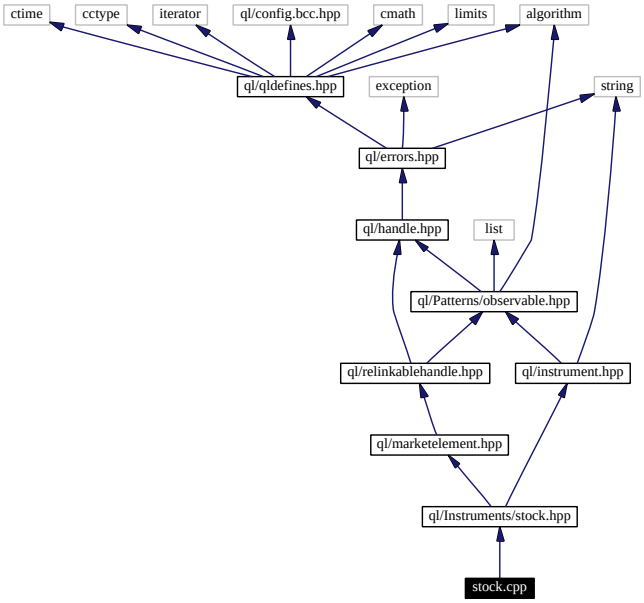
Full path:
ql/Utilities/steppingiterator.hpp

12.243 stock.cpp File Reference

concrete stock class.

`#include <ql/Instruments/stock.hpp>`

Include dependency graph for stock.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.243.1 Detailed Description

Full path:
ql/Instruments/stock.cpp

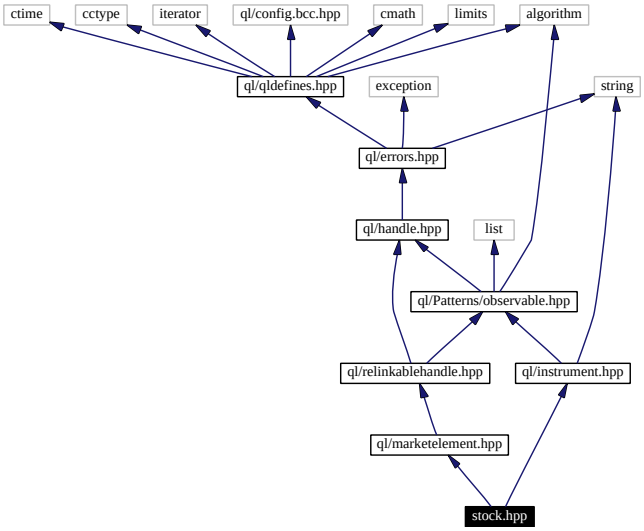
12.244 stock.hpp File Reference

concrete stock class.

`#include <ql/instrument.hpp>`

`#include <ql/marketelement.hpp>`

Include dependency graph for stock.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.244.1 Detailed Description

Full path:
ql/Instruments/stock.hpp

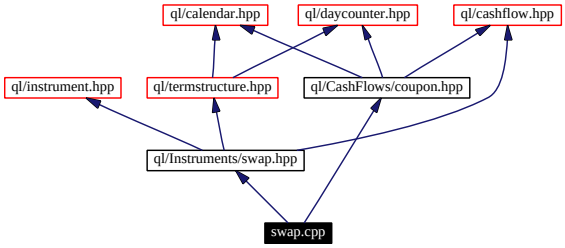
12.245 swap.cpp File Reference

Interest rate swap.

`#include <ql/Instruments/swap.hpp>`

`#include <ql/CashFlows/coupon.hpp>`

Include dependency graph for swap.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.245.1 Detailed Description

Full path:
ql/Instruments/swap.cpp

12.246 swap.hpp File Reference

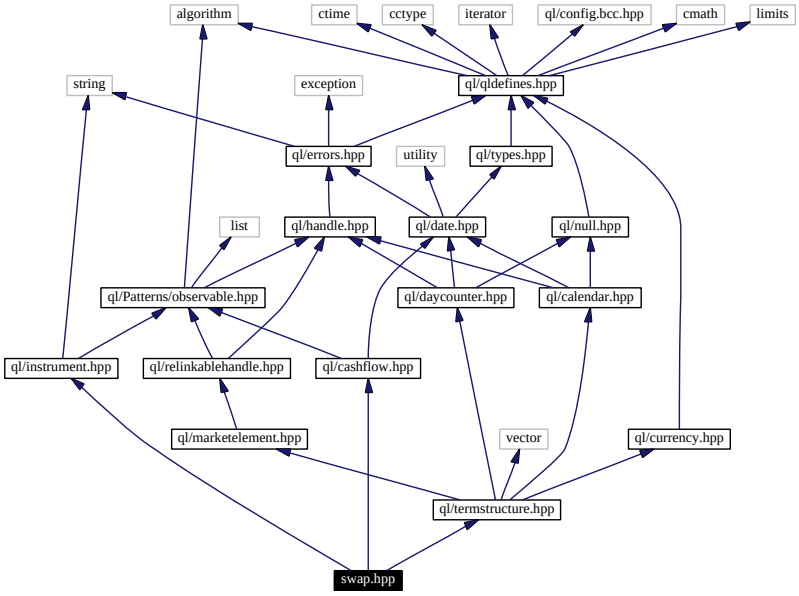
Interest rate swap.

`#include <ql/instrument.hpp>`

`#include <ql/cashflow.hpp>`

`#include <ql/termstructure.hpp>`

Include dependency graph for swap.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.246.1 Detailed Description

Full path:
ql/Instruments/swap.hpp

12.247 swaption.cpp File Reference

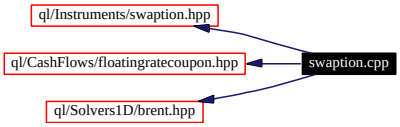
Swaption.

`#include <ql/Instruments/swaption.hpp>`

`#include <ql/CashFlows/floatingratecoupon.hpp>`

`#include <ql/Solvers1D/brent.hpp>`

Include dependency graph for swaption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments

12.247.1 Detailed Description

Full path:
ql/Instruments/swaption.cpp

12.248 swaption.hpp File Reference

Swaption class.

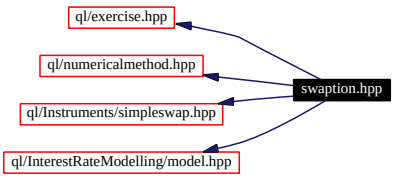
`#include <ql/exercise.hpp>`

`#include <ql/numericalmethod.hpp>`

`#include <ql/Instruments/simpleswap.hpp>`

`#include <ql/InterestRateModelling/model.hpp>`

Include dependency graph for swaption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Instruments
- namespace QuantLib::Pricers

12.248.1 Detailed Description

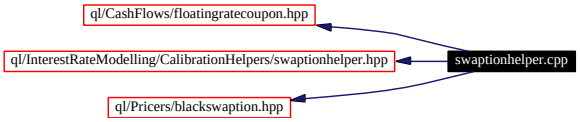
Full path:
ql/Instruments/swaption.hpp

12.249 swaptionhelper.cpp File Reference

Swaption calibration helper.

```
#include "ql/CashFlows/floatingratecoupon.hpp"
#include "ql/InterestRateModelling/CalibrationHelpers/swaptionhelper.hpp"
#include "ql/Pricers/blackswaption.hpp"
```

Include dependency graph for swaptionhelper.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**
- namespace **QuantLib::InterestRateModelling::CalibrationHelpers**

12.249.1 Detailed Description

Full path:
ql/InterestRateModelling/CalibrationHelpers/swaptionhelper.cpp

12.250 swaptionhelper.hpp File Reference

Swaption calibration helper.

`#include <ql/InterestRateModelling/calibrationhelper.hpp>`

`#include <ql/Instruments/swaption.hpp>`

Include dependency graph for swaptionhelper.hpp:

Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**
- namespace **QuantLib::InterestRateModelling::CalibrationHelpers**

12.250.1 Detailed Description

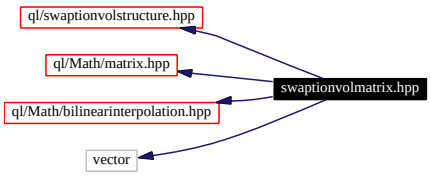
Full path:
ql/InterestRateModelling/CalibrationHelpers/swaptionhelper.hpp

12.251 swaptionvolmatrix.hpp File Reference

Swaption at-the-money volatility matrix.

```
#include "ql/swaptionvolstructure.hpp"
#include "ql/Math/matrix.hpp"
#include "ql/Math/bilinearinterpolation.hpp"
#include <vector>
```

Include dependency graph for swaptionvolmatrix.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Volatilities**

12.251.1 Detailed Description

Full path:
ql/Volatilities/swaptionvolmatrix.hpp

12.252 swaptionvolstructure.hpp File Reference

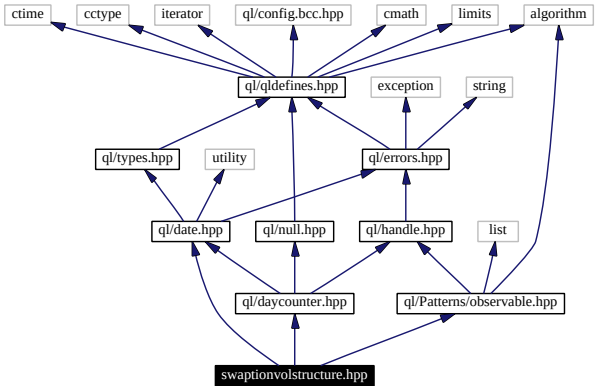
Swaption volatility structure.

`#include <ql/date.hpp>`

`#include <ql/daycounter.hpp>`

`#include <ql/Patterns/observable.hpp>`

Include dependency graph for swaptionvolstructure.hpp:



Namespaces

- namespace QuantLib

12.252.1 Detailed Description

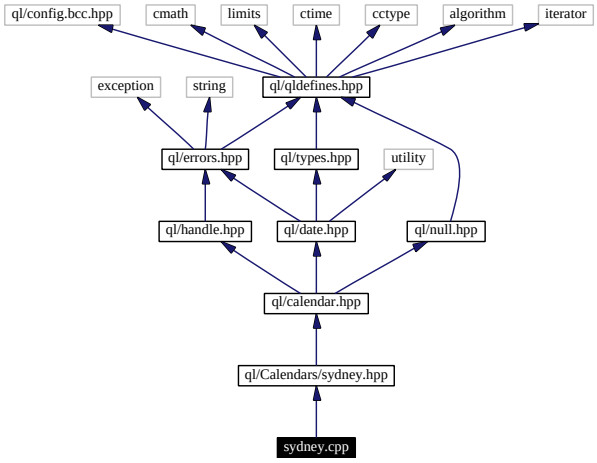
Full path:
ql/swaptionvolstructure.hpp

12.253 sydney.cpp File Reference

Sydney calendar.

`#include <ql/Calendars/sydney.hpp>`

Include dependency graph for sydney.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.253.1 Detailed Description

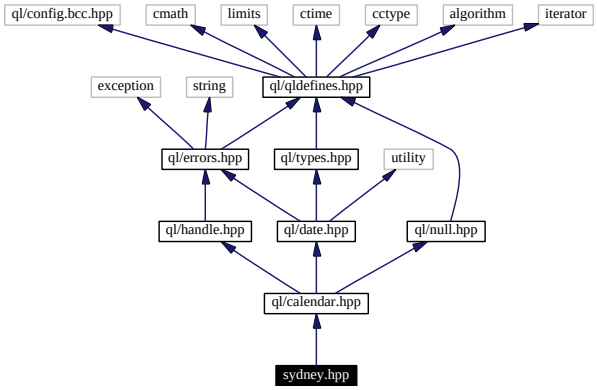
Full path:
ql/Calendars/sydney.cpp

12.254 sydney.hpp File Reference

Sydney calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for sydney.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.254.1 Detailed Description

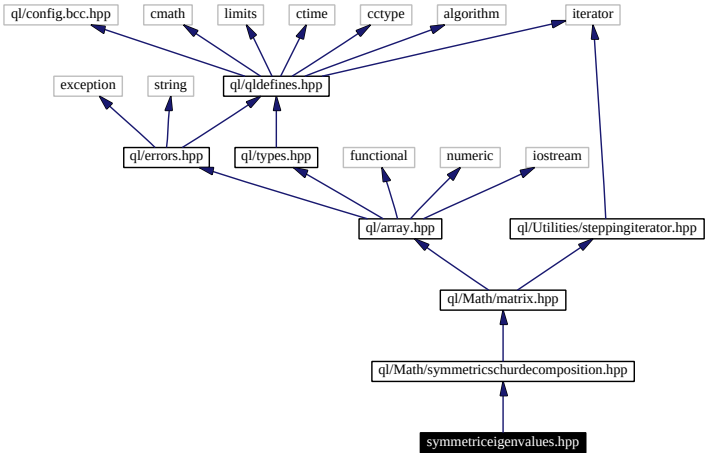
Full path:
ql/Calendars/sydney.hpp

12.255 symmetriceigenvalues.hpp File Reference

Eigenvalues / eigenvectors of a real symmetric matrix.

`#include <ql/Math/symmetricschurdecomposition.hpp>`

Include dependency graph for symmetriceigenvalues.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.255.1 Detailed Description

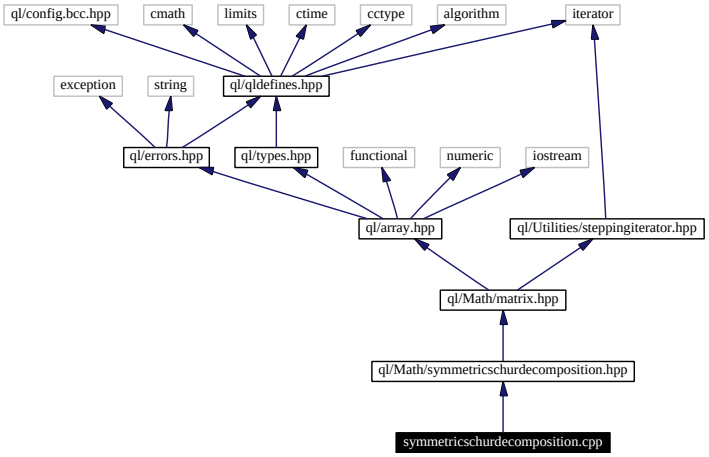
Full path:
ql/Math/symmetriceigenvalues.hpp

12.256 symmetricschurdecomposition.cpp File Reference

Eigenvalues / eigenvectors of a real symmetric matrix.

`#include <ql/Math/symmetricschurdecomposition.hpp>`

Include dependency graph for symmetricschurdecomposition.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.256.1 Detailed Description

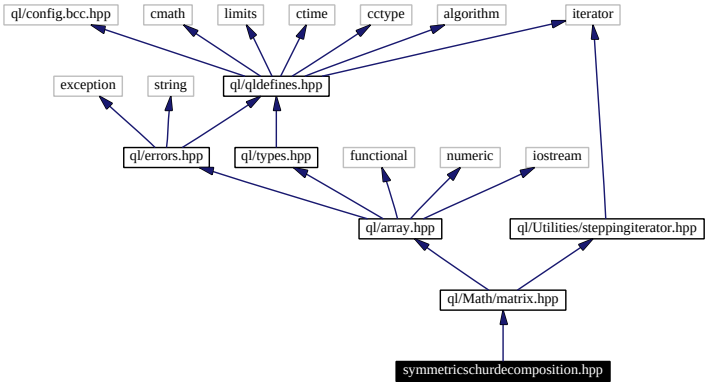
Full path:
ql/Math/symmetricschurdecomposition.cpp

12.257 symmetricschurdecomposition.hpp File Reference

Eigenvalues / eigenvectors of a real symmetric matrix.

`#include <ql/Math/matrix.hpp>`

Include dependency graph for symmetricschurdecomposition.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Math

12.257.1 Detailed Description

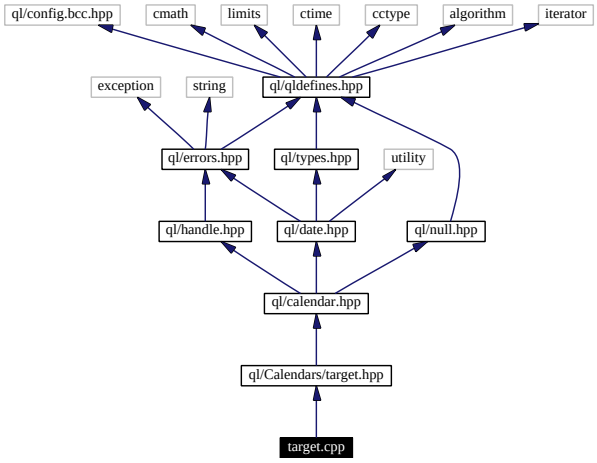
Full path:
ql/Math/symmetricschurdecomposition.hpp

12.258 target.cpp File Reference

TARGET calendar.

`#include <ql/Calendars/target.hpp>`

Include dependency graph for target.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.258.1 Detailed Description

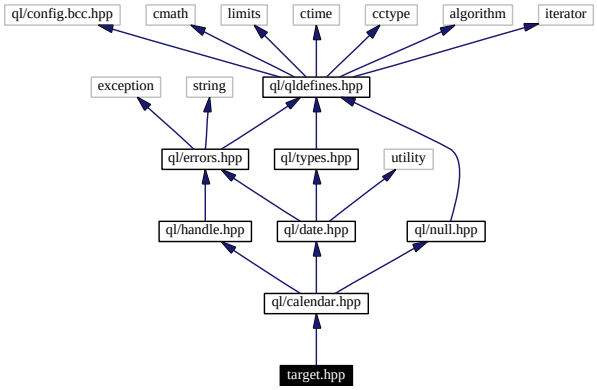
Full path:
ql/Calendars/target.cpp

12.259 target.hpp File Reference

TARGET calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for target.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.259.1 Detailed Description

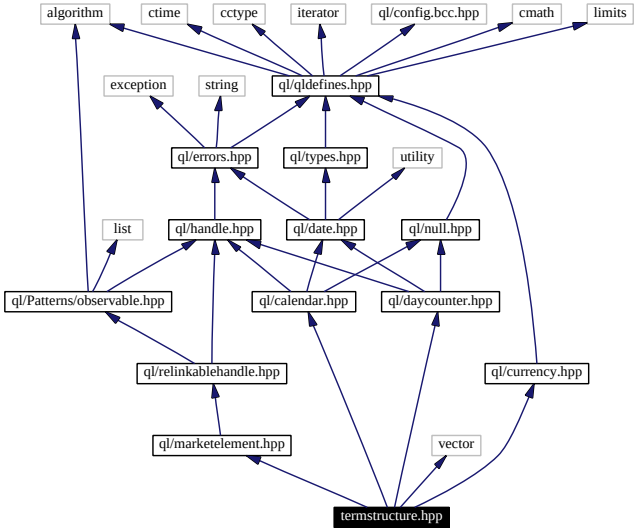
Full path:
ql/Calendars/target.hpp

12.260 termstructure.hpp File Reference

Term structure.

```
#include <ql/calendar.hpp>
#include <ql/currency.hpp>
#include <ql/daycounter.hpp>
#include <ql/marketelement.hpp>
#include <vector>
```

Include dependency graph for termstructure.hpp:



Namespaces

- namespace QuantLib::TermStructures
- namespace QuantLib

12.260.1 Detailed Description

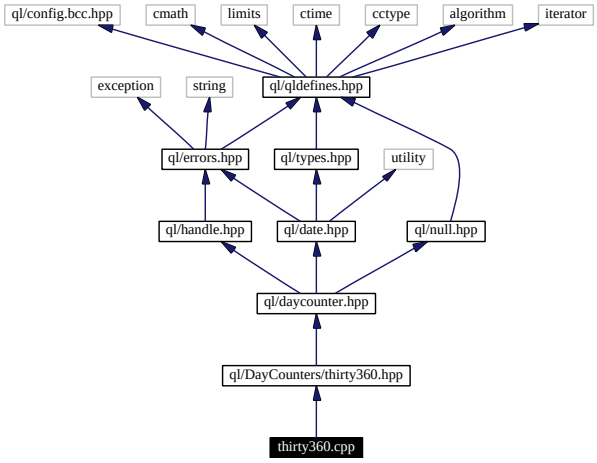
Full path:
ql/termstructure.hpp

12.261 thirty360.cpp File Reference

30/360 day counters.

`#include <ql/DayCounters/thirty360.hpp>`

Include dependency graph for thirty360.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.261.1 Detailed Description

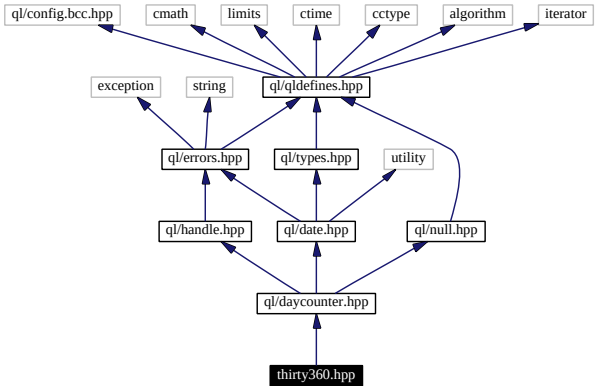
Full path:
ql/DayCounters/thirty360.cpp

12.262 thirty360.hpp File Reference

30/360 day counters.

`#include <ql/daycounter.hpp>`

Include dependency graph for thirty360.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::DayCounters

12.262.1 Detailed Description

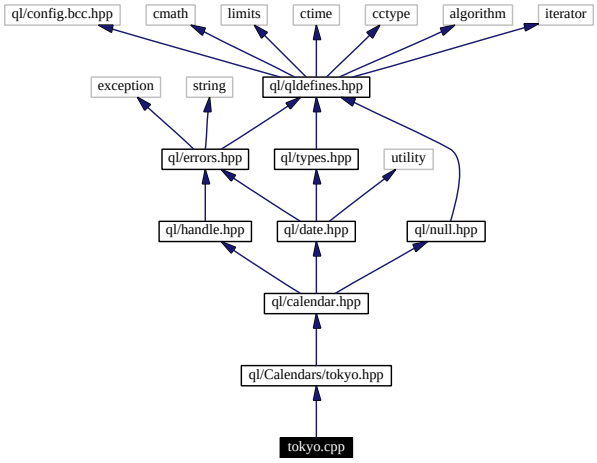
Full path:
ql/DayCounters/thirty360.hpp

12.263 tokyo.cpp File Reference

Tokyo calendar.

`#include <ql/Calendars/tokyo.hpp>`

Include dependency graph for tokyo.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.263.1 Detailed Description

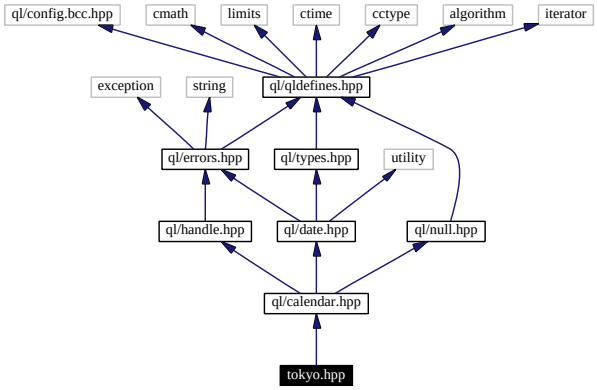
Full path:
ql/Calendars/tokyo.cpp

12.264 tokyo.hpp File Reference

Tokyo calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for tokyo.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.264.1 Detailed Description

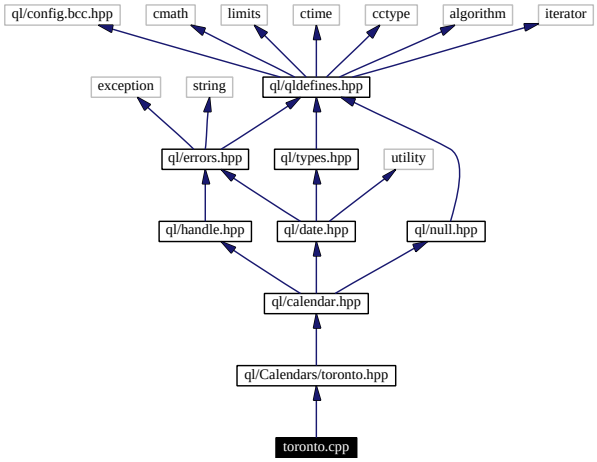
Full path:
ql/Calendars/tokyo.hpp

12.265 toronto.cpp File Reference

Toronto calendar.

`#include <ql/Calendars/toronto.hpp>`

Include dependency graph for toronto.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.265.1 Detailed Description

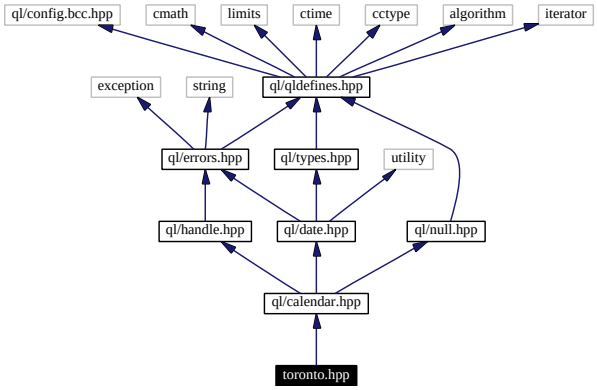
Full path:
Calendars/toronto.cpp

12.266 toronto.hpp File Reference

Toronto calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for toronto.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.266.1 Detailed Description

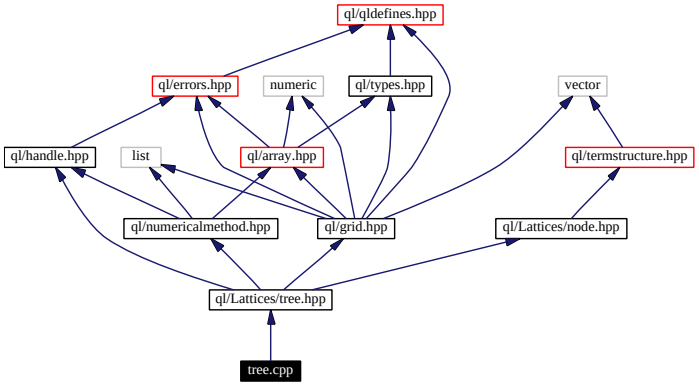
Full path:
ql/Calendars/toronto.hpp

12.267 tree.cpp File Reference

Tree class.

`#include "ql/Lattices/tree.hpp"`

Include dependency graph for tree.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.267.1 Detailed Description

Full path:
ql/Lattices/tree.cpp

12.268 tree.hpp File Reference

Tree class.

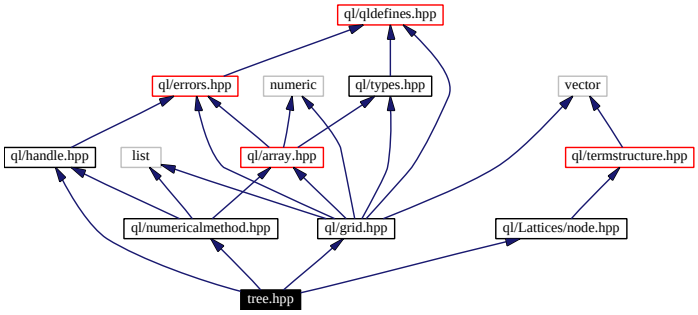
`#include <ql/numericalmethod.hpp>`

`#include <ql/handle.hpp>`

`#include <ql/grid.hpp>`

`#include <ql/Lattices/node.hpp>`

Include dependency graph for tree.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.268.1 Detailed Description

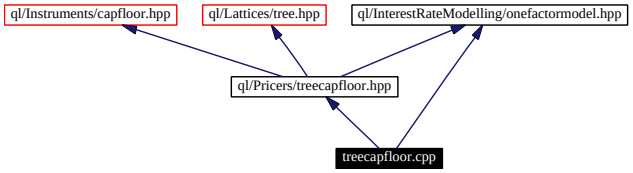
Full path:
ql/Lattices/tree.hpp

12.269 treecapfloor.cpp File Reference

Cap/Floor calculated using a tree.

```
#include "ql/Pricers/treecapfloor.hpp"
#include "ql/InterestRateModelling/onefactormodel.hpp"
```

Include dependency graph for treecapfloor.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.269.1 Detailed Description

Full path:
ql/Pricers/treecapfloor.cpp

12.270 treecapfloor.hpp File Reference

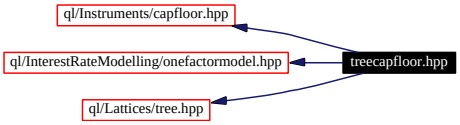
Cap/Floor calculated using a tree.

`#include <ql/Instruments/capfloor.hpp>`

`#include <ql/InterestRateModelling/onefactormodel.hpp>`

`#include <ql/Lattices/tree.hpp>`

Include dependency graph for treecapfloor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.270.1 Detailed Description

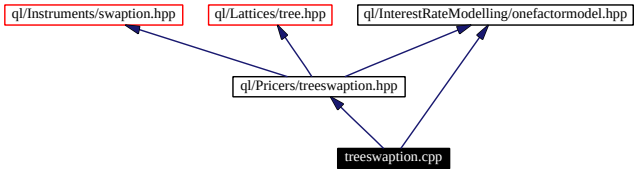
Full path:
ql/Pricers/treecapfloor.hpp

12.271 treeswaption.cpp File Reference

European swaption calculated using finite differences.

```
#include "ql/Pricers/treeswaption.hpp"
#include "ql/InterestRateModelling/onefactormodel.hpp"
```

Include dependency graph for treeswaption.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.271.1 Detailed Description

Full path:
ql/Pricers/treeswaption.cpp

12.272 treeswaption.hpp File Reference

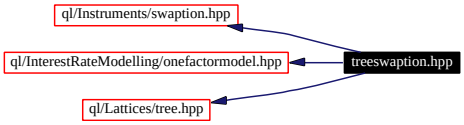
Swaption calculated using a tree.

`#include <ql/Instruments/swaption.hpp>`

`#include <ql/InterestRateModelling/onefactormodel.hpp>`

`#include <ql/Lattices/tree.hpp>`

Include dependency graph for treeswaption.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Pricers

12.272.1 Detailed Description

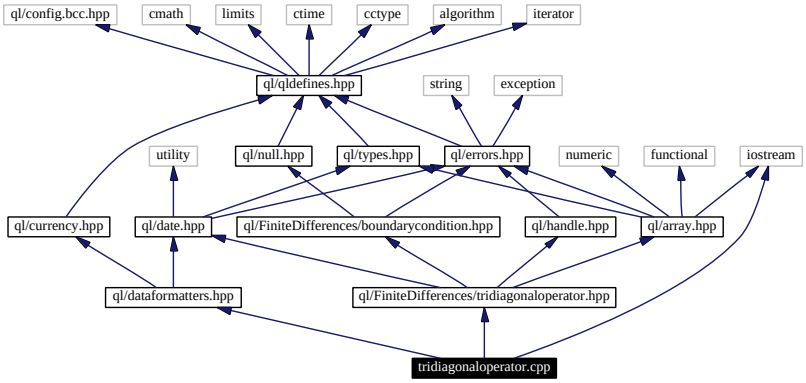
Full path:
ql/Pricers/treeswaption.hpp

12.273 tridiagonaloperator.cpp File Reference

tridiagonal operator.

```
#include <ql/FiniteDifferences/tridiagonaloperator.hpp>
#include <ql/dataformatters.hpp>
#include <iostream>
```

Include dependency graph for tridiagonaloperator.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.273.1 Detailed Description

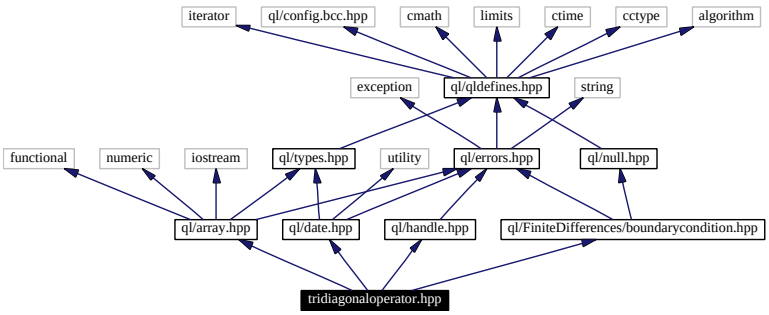
Full path:
ql/FiniteDifferences/tridiagonaloperator.cpp

12.274 tridiagonaloperator.hpp File Reference

tridiagonal operator.

```
#include <ql/FiniteDifferences/boundarycondition.hpp>
#include <ql/array.hpp>
#include <ql/date.hpp>
#include <ql/handle.hpp>
```

Include dependency graph for tridiagonaloperator.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.274.1 Detailed Description

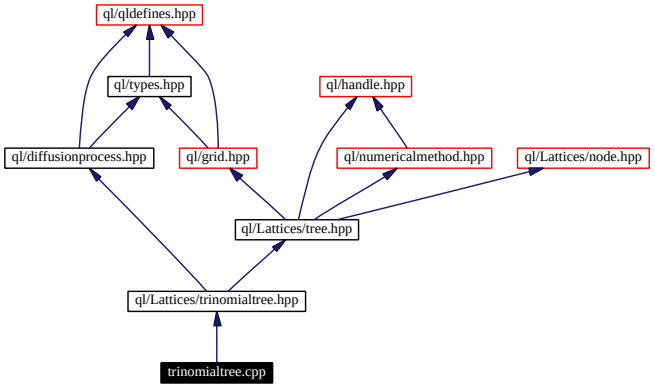
Full path:
ql/FiniteDifferences/tridiagonaloperator.hpp

12.275 trinomialtree.cpp File Reference

Trinomial tree class.

`#include "ql/Lattices/trinomialtree.hpp"`

Include dependency graph for trinomialtree.cpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.275.1 Detailed Description

Full path:
ql/Lattices/trinomialtree.cpp

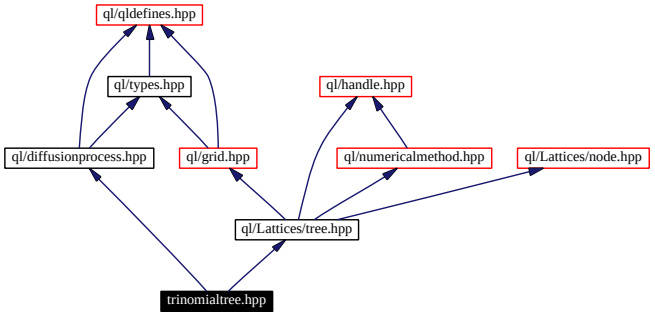
12.276 trinomialtree.hpp File Reference

Trinomial tree class.

`#include <ql/diffusionprocess.hpp>`

`#include <ql/Lattices/tree.hpp>`

Include dependency graph for trinomialtree.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::Lattices**

12.276.1 Detailed Description

Full path:
ql/Lattices/trinomialtree.hpp

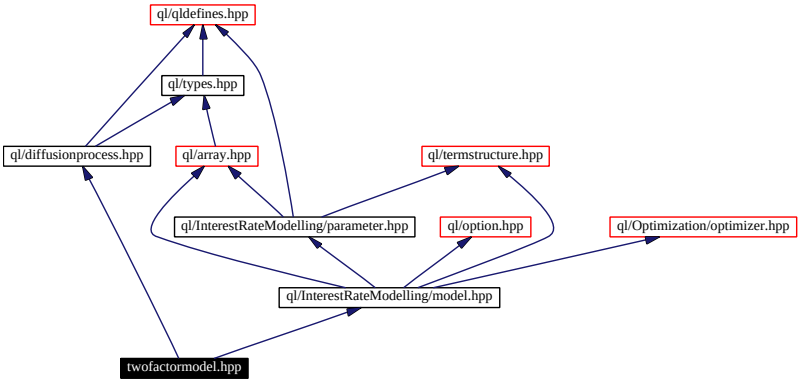
12.277 twofactormodel.hpp File Reference

Abstract two-factor interest rate model class.

`#include <ql/diffusionprocess.hpp>`

`#include <ql/InterestRateModelling/model.hpp>`

Include dependency graph for twofactormodel.hpp:



Namespaces

- namespace QuantLib
- namespace **QuantLib::InterestRateModelling**

12.277.1 Detailed Description

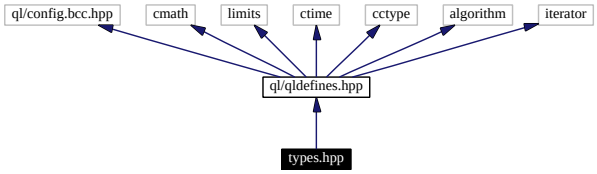
Full path:
ql/InterestRateModelling/twofactormodel.hpp

12.278 types.hpp File Reference

Custom types.

`#include <ql/qldefines.hpp>`

Include dependency graph for types.hpp:



Namespaces

- namespace QuantLib

12.278.1 Detailed Description

Full path:
ql/types.hpp

12.279 usdlibor.hpp File Reference

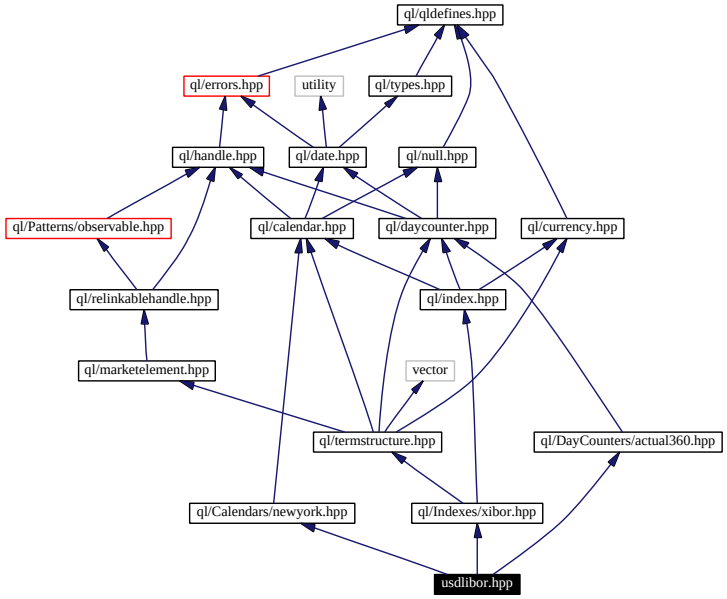
USD Libor index.

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/newyork.hpp>`

`#include <ql/DayCounters/actual360.hpp>`

Include dependency graph for usdlibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.279.1 Detailed Description

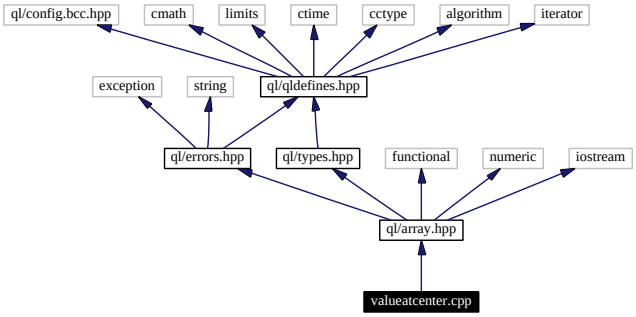
Full path:
ql/Indexes/usdlibor.hpp

12.280 valueatcenter.cpp File Reference

compute value, first, and second derivatives at grid center.

`#include <ql/array.hpp>`

Include dependency graph for valueatcenter.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.280.1 Detailed Description

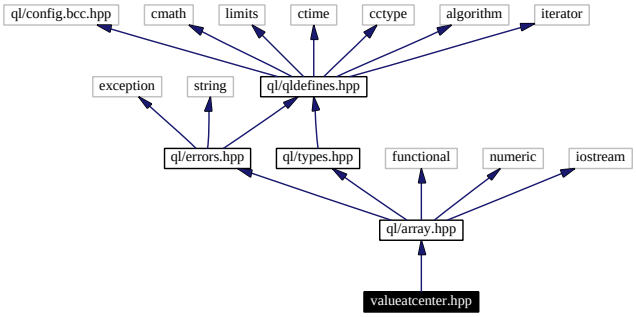
Full path:
ql/FiniteDifferences/valueatcenter.cpp

12.281 valueatcenter.hpp File Reference

compute value, first, and second derivatives at grid center.

`#include <ql/array.hpp>`

Include dependency graph for valueatcenter.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::FiniteDifferences

12.281.1 Detailed Description

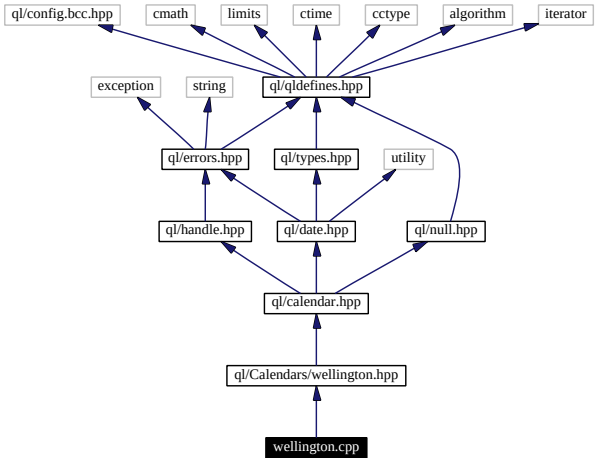
Full path:
ql/FiniteDifferences/valueatcenter.hpp

12.282 wellington.cpp File Reference

Wellington calendar.

`#include <ql/Calendars/wellington.hpp>`

Include dependency graph for wellington.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.282.1 Detailed Description

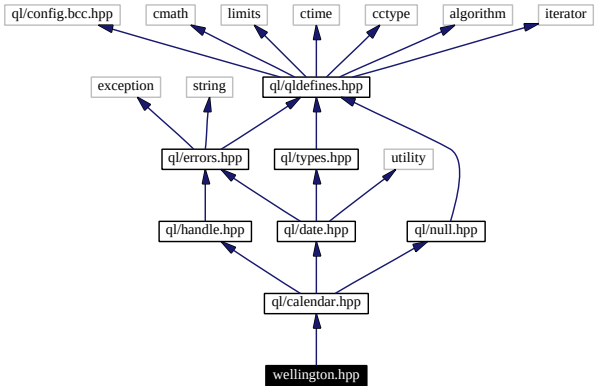
Full path:
ql/Calendars/wellington.cpp

12.283 wellington.hpp File Reference

Wellington calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for wellington.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.283.1 Detailed Description

Full path:
ql/Calendars/wellington.hpp

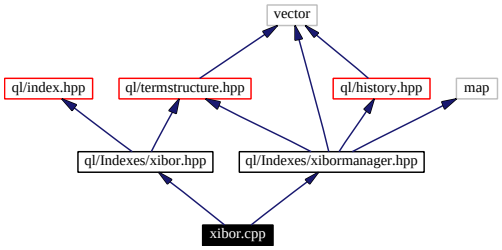
12.284 xibor.cpp File Reference

purely virtual base class for libor indexes.

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Indexes/xibormanager.hpp>`

Include dependency graph for xibor.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.284.1 Detailed Description

Full path:
ql/Indexes/xibor.cpp

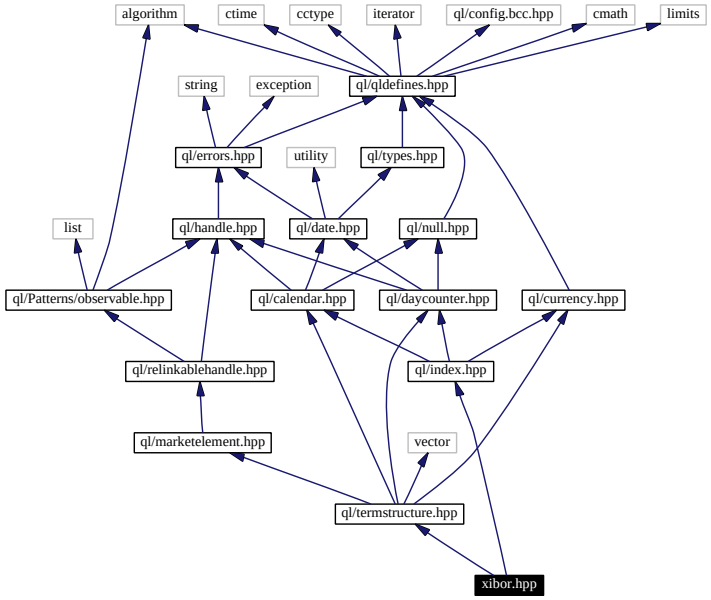
12.285 xibor.hpp File Reference

purely virtual base class for libor indexes.

`#include <ql/index.hpp>`

`#include <ql/termstructure.hpp>`

Include dependency graph for xibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.285.1 Detailed Description

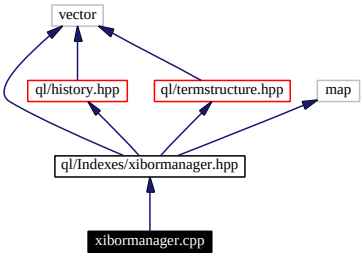
Full path:
ql/Indexes/xibor.hpp

12.286 xibormanager.cpp File Reference

global repository for Xibor histories.

`#include <ql/Indexes/xibormanager.hpp>`

Include dependency graph for xibormanager.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.286.1 Detailed Description

Full path:
ql/Indexes/xibormanager.cpp

12.287 xibormanager.hpp File Reference

global repository for Xibor histories.

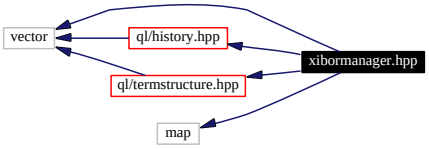
`#include <ql/history.hpp>`

`#include <ql/termstructure.hpp>`

`#include <map>`

`#include <vector>`

Include dependency graph for xibormanager.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.287.1 Detailed Description

Full path:
ql/Indexes/xibormanager.hpp

12.288 zarlibor.hpp File Reference

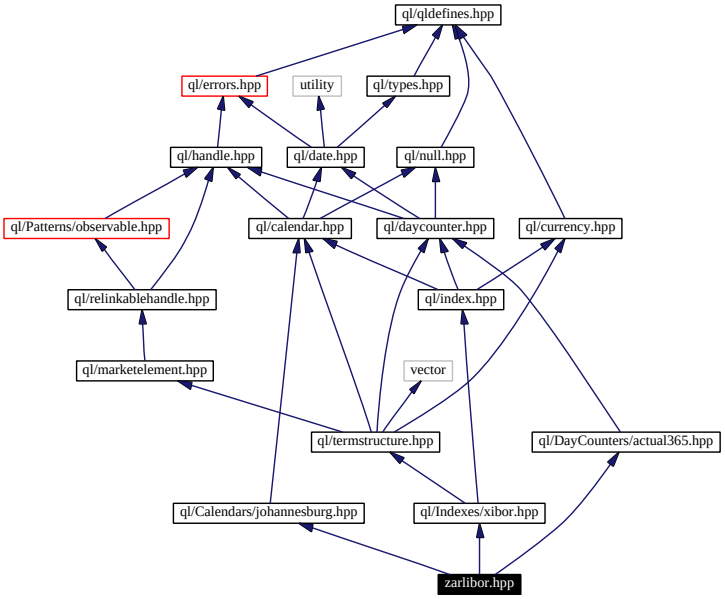
ZAR Libor index (also known as JIBAR, check settlement days).

`#include <ql/Indexes/xibor.hpp>`

`#include <ql/Calendars/johannesburg.hpp>`

`#include <ql/DayCounters/actual365.hpp>`

Include dependency graph for zarlibor.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Indexes

12.288.1 Detailed Description

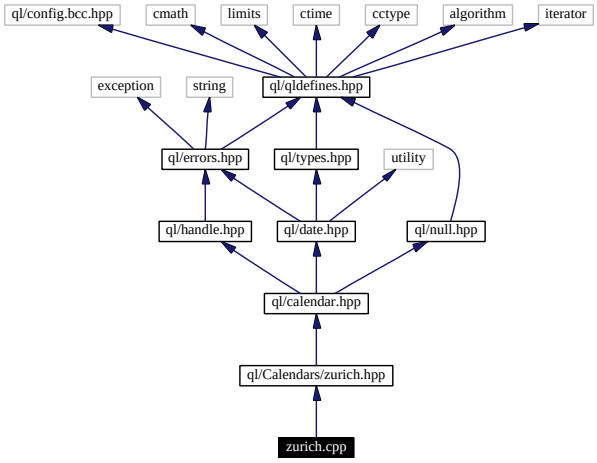
Full path:
ql/Indexes/zarlibor.hpp

12.289 zurich.cpp File Reference

Zurich calendar.

`#include <ql/Calendars/zurich.hpp>`

Include dependency graph for zurich.cpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.289.1 Detailed Description

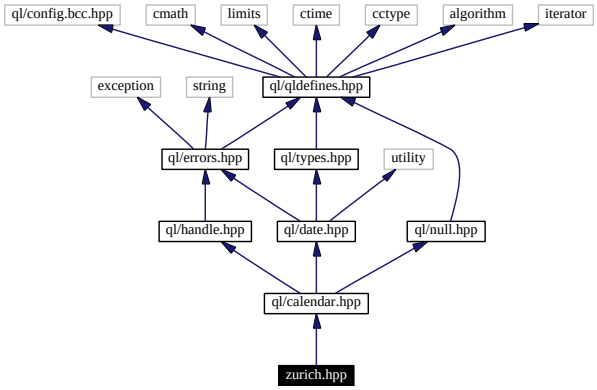
Full path:
ql/Calendars/zurich.cpp

12.290 zurich.hpp File Reference

Zurich calendar.

`#include <ql/calendar.hpp>`

Include dependency graph for zurich.hpp:



Namespaces

- namespace QuantLib
- namespace QuantLib::Calendars

12.290.1 Detailed Description

Full path:
ql/Calendars/zurich.hpp

Chapter 13

QuantLib Example Documentation

13.1 DiscreteHedging.cpp

This is an example of using the QuantLib Monte Carlo framework.

```
/*  This example computes profit and loss of a discrete interval hedging
    strategy and compares with the results of Derman & Kamal's (Goldman Sachs
    Equity Derivatives Research) Research Note: "When You Cannot Hedge
    Continuously: The Corrections to Black-Scholes"
    (http://www.gs.com/qs/doc/when_you_cannot_hedge.pdf)

    Suppose an option hedger sells an European option and receives the
    Black-Scholes value as the options premium.
    Then he follows a Black-Scholes hedging strategy, rehedging at discrete,
    evenly spaced time intervals as the underlying stock changes. At
    expiration, the hedger delivers the option payoff to the option holder,
    and unwinds the hedge. We are interested in understanding the final
    profit or loss of this strategy.

    If the hedger had followed the exact Black-Scholes replication strategy,
    re-hedging continuously as the underlying stock evolved towards its final
    value at expiration, then, no matter what path the stock took, the final
    P&L would be exactly zero. When the replication strategy deviates from
    the exact Black-Scholes method, the final P&L may deviate from zero. This
    deviation is called the replication error. When the hedger rebalances at
    discrete rather than continuous intervals, the hedge is imperfect and the
    replication is inexact. The more often hedging occurs, the smaller the
    replication error.

    We examine the range of possibilities, computing the replication error.
*/

// the only header you need to use QuantLib
#include <ql/quantlib.hpp>


// introducing the players ....

// Rate and Time are just double, but having their own types allows for
// a stronger check at compile time
using QuantLib::Rate;
using QuantLib::Time;
```

```
// Option is a helper class that holds the enumeration {Call, Put, Straddle}
using QuantLib::Option;

// Handle is the QuantLib way to have reference-counted objects
using QuantLib::Handle;

// helper function for option payoff: MAX((stike-underlying),0), etc.
using QuantLib::Pricers::ExercisePayoff;

// the classic Black Scholes analytic solution for European Option
using QuantLib::Pricers::EuropeanOption;

// class for statistical analysis
using QuantLib::Math::Statistics;

// single Path of a random variable
// It contains the list of variations
using QuantLib::MonteCarlo::Path;

// the pricer computes final portfolio's value for each random variable path
using QuantLib::MonteCarlo::PathPricer;

// the path generator
using QuantLib::MonteCarlo::GaussianPathGenerator;

// the Montecarlo pricing model for option on a single asset
using QuantLib::MonteCarlo::OneFactorMonteCarloOption;

// to format the output of doubles
using QuantLib::DoubleFormatter;

/* The ReplicationError class carries out Monte Carlo simulations to evaluate
   the outcome (the replication error) of the discrete hedging strategy over
   different, randomly generated scenarios of future stock price evolution.
*/
class ReplicationError
{
public:
    ReplicationError(Option::Type type,
                     Time maturity,
                     double strike,
                     double s0,
                     double sigma,
                     Rate r)
    : type_(type), maturity_(maturity), strike_(strike), s0_(s0),
      sigma_(sigma), r_(r) {

        // value of the option
        EuropeanOption option = EuropeanOption(type_, s0_, strike_, 0.0, r_,
            maturity_, sigma_);
        std::cout << "Option value: " << option.value() << std::endl;

        // store option's vega, since Derman and Kamal's formula needs it
        vega_ = option.vega();

        std::cout << std::endl;
        std::cout <<
            "        |        | P&L  \t|  P&L    | Derman&Kamal | P&L"
            "      \t| P&L" << std::endl;

        std::cout <<
            "samples | trades | Mean \t| Std Dev | Formula      |"
            " skewness \t| kurt." << std::endl;

        std::cout << "---------------------------------"
```

```
            "-------------------------------------------" << std::endl;
    }

    // the actual replication error computation
    void compute(int nTimeSteps, int nSamples);
private:
    Option::Type type_;
    Time maturity_;
    double strike_, s0_;
    double sigma_;
    Rate r_;
    double vega_;
};

// The key for the MonteCarlo simulation is to have a PathPricer that
// implements a value(const Path& path) method.
// This method prices the portfolio for each Path of the random variable
class ReplicationPathPricer : public PathPricer<Path>
{
  public:
    // real constructor
    ReplicationPathPricer(Option::Type type,
                          double underlying,
                          double strike,
                          Rate r,
                          Time maturity,
                          double sigma)
    : PathPricer<Path>(1.0, false), type_(type), underlying_(underlying),
      strike_(strike), r_(r), maturity_(maturity), sigma_(sigma) {
        QL_REQUIRE(strike_ > 0.0,
            "ReplicationPathPricer: strike must be positive");
        QL_REQUIRE(underlying_ > 0.0,
            "ReplicationPathPricer: underlying must be positive");
        QL_REQUIRE(r_ >= 0.0,
            "ReplicationPathPricer: risk free rate (r) must"
            " be positive or zero");
        QL_REQUIRE(maturity_ > 0.0,
            "ReplicationPathPricer: maturity must be positive");
        QL_REQUIRE(sigma_ >= 0.0,
            "ReplicationPathPricer: volatility (sigma)"
            " must be positive or zero");

    }
    // The value() method encapsulates the pricing code
    double operator()(const Path& path) const;

  private:
    Option::Type type_;
    double underlying_, strike_;
    Rate r_;
    Time maturity_;
    double sigma_;
};


// Compute Replication Error as in the Derman and Kamal's research note
int main(int argc, char* argv[])
{
    try {
        Time maturity = 1./12.;   // 1 month
        double strike = 100;
        double underlying = 100;
        double volatility = 0.20; // 20%
        Rate riskFreeRate = 0.05; // 5%
        ReplicationError rp(Option::Call, maturity, strike, underlying,
```

```
                volatility, riskFreeRate);

        int scenarios = 50000;
        int hedgesNum;

        hedgesNum = 21;
        rp.compute(hedgesNum, scenarios);

        hedgesNum = 84;
        rp.compute(hedgesNum, scenarios);

        return 0;
    } catch (std::exception& e) {
        std::cout << e.what() << std::endl;
        return 1;
    } catch (...) {
        std::cout << "unknown error" << std::endl;
        return 1;
    }
}


/* The actual computation of the Profit&Loss for each single path.

   In each scenario N rehedging trades spaced evenly in time over
   the life of the option are carried out, using the Black-Scholes
   hedge ratio.
*/
double ReplicationPathPricer::operator()(const Path& path) const
{

    // path is an instance of QuantLib::MonteCarlo::Path
    // It contains the list of variations.
    // It can be used as an array: it has a size() method
    int n = path.size();
    QL_REQUIRE(n>0,
        "ReplicationPathPricer: the path cannot be empty");

    // discrete hedging interval
    Time dt = maturity_/n;

    // For simplicity, we assume the stock pays no dividends.
    double stockDividendYield = 0.0;

    // let's start
    Time t = 0;

    // stock value at t=0
    double stock = underlying_;
    double stockLogGrowth = 0.0;

    // money account at t=0
    double money_account = 0.0;

    /************************/
    /*** the initial deal ***/
    /************************/
    // option fair price (Black-Scholes) at t=0
    EuropeanOption option = EuropeanOption(type_, stock, strike_,
        stockDividendYield, r_, maturity_, sigma_);
    // sell the option, cash in its premium
    money_account += option.value();
    // compute delta
    double delta = option.delta();
    // delta-hedge the option buying stock
```

```
    double stockAmount = delta;
    money_account -= stockAmount*stock;

    /*********************************/
    /*** hedging during option life ***/
    /*********************************/
    for(int step = 0; step < n-1; step++){

        // time flows
        t += dt;

        // accruing on the money account
        money_account *= QL_EXP( r_*dt );

        // stock growth:
        // path contains the list of Gaussian variations
        // and path[n] is the n-th variation
        stockLogGrowth += path[step];
        stock = underlying_*QL_EXP(stockLogGrowth);

        // recalculate option value at the current stock value,
        // and the current time to maturity
        EuropeanOption option = EuropeanOption(type_, stock, strike_,
            stockDividendYield, r_, maturity_-t, sigma_);

        // recalculate delta
        delta = option.delta();

        // re-hedging
        money_account -= (delta - stockAmount)*stock;
        stockAmount = delta;
    }

    /************************/
    /*** option expiration ***/
    /************************/
    // last accrual on my money account
    money_account *= QL_EXP( r_*dt );
    // last stock growth
    stockLogGrowth += path[n-1];
    stock = underlying_*QL_EXP(stockLogGrowth);

    // the hedger delivers the option payoff to the option holder
    double optionPayoff = ExercisePayoff(type_, stock, strike_);
    money_account -= optionPayoff;

    // and unwinds the hedge selling his stock position
    money_account += stockAmount*stock;

    // final Profit&Loss
    return money_account;
}


// The computation over nSamples paths of the P&L distribution
void ReplicationError::compute(int nTimeSteps, int nSamples)
{
    QL_REQUIRE(nTimeSteps>0,
        "ReplicationError::compute : the number of steps must be > 0");

    // hedging interval
    // double tau = maturity_ / nTimeSteps;

    /* Black-Scholes framework: the underlying stock price evolves
       lognormally with a fixed known volatility that stays constant
```

```
       throughout time.
    */
    double drift = r_ - 0.5*sigma_*sigma_;

    // Black Scholes equation rules the path generator:
    // at each step the log of the stock
    // will have drift and sigma^2 variance
    Handle<GaussianPathGenerator> myPathGenerator(
        new GaussianPathGenerator(drift, sigma_*sigma_,
            maturity_, nTimeSteps));

    // The replication strategy's Profit&Loss is computed for each path
    // of the stock. The path pricer knows how to price a path using its
    // value() method
    Handle<PathPricer<Path> > myPathPricer =
        Handle<PathPricer<Path> >(new ReplicationPathPricer(type_, s0_, strike_, r_,
            maturity_, sigma_));

    // a statistic accumulator for the path-dependant Profit&Loss values
    Statistics statisticAccumulator;

    // The OneFactorMontecarloModel generates paths using myPathGenerator
    // each path is priced using myPathPricer
    // prices will be accumulated into statisticAccumulator
    OneFactorMonteCarloOption MCSimulation(myPathGenerator,
        myPathPricer, statisticAccumulator);

    // the model simulates nSamples paths
    MCSimulation.addSamples(nSamples);

    // the sampleAccumulator method of OneFactorMonteCarloOption
    // gives access to all the methods of statisticAccumulator
    double PLMean  = MCSimulation.sampleAccumulator().mean();
    double PLStDev = MCSimulation.sampleAccumulator().standardDeviation();
    double PLSkew  = MCSimulation.sampleAccumulator().skewness();
    double PLKurt  = MCSimulation.sampleAccumulator().kurtosis();

    // Derman and Kamal's formula
    double theorStD = QL_SQRT(3.1415926535/4/nTimeSteps)*vega_*sigma_;


    std::cout << nSamples << "\t| "
        << nTimeSteps << "\t | "
        << DoubleFormatter::toString(PLMean,   3) << " \t| "
        << DoubleFormatter::toString(PLStDev,  2) << " \t  | "
        << DoubleFormatter::toString(theorStD, 2) << " \t | "
        << DoubleFormatter::toString(PLSkew,   2) << " \t| "
        << DoubleFormatter::toString(PLKurt,   2) << std::endl;
}
```

13.2 EuropeanOption.cpp

This example calculates European call options using different methods while testing call-put parity.

```
#include <ql/quantlib.hpp>

using namespace QuantLib;

using QuantLib::Pricers::EuropeanOption;
using QuantLib::Pricers::McEuropean;
using QuantLib::Pricers::FdEuropean;

// helper function for option payoff: MAX((stike-underlying),0), etc.
using QuantLib::Pricers::ExercisePayoff;

// This will be included in the library after a bit of redesign
class Payoff : public QL::ObjectiveFunction{
    public:
        Payoff(Time maturity,
               double strike,
               double s0,
               double sigma,
               Rate r)
        : maturity_(maturity),
        strike_(strike),
        s0_(s0),
        sigma_(sigma),r_(r){}

        double operator()(double x) const {
           double nuT = (r_-0.5*sigma_*sigma_)*maturity_;
           return QL_EXP(-r_*maturity_)
               *ExercisePayoff(Option::Call, s0_*QL_EXP(x), strike_)
               *QL_EXP(-(x - nuT)*(x -nuT)/(2*sigma_*sigma_*maturity_))
               /QL_SQRT(2.0*3.141592*sigma_*sigma_*maturity_);
        }
private:
    Time maturity_;
    double strike_;
    double s0_;
    double sigma_;
    Rate r_;
};


int main(int argc, char* argv[])
{
    try {
        // our option
        double underlying = 102;
        double strike = 100;      // at the money
        Spread dividendYield = 0.0; // no dividends
        Rate riskFreeRate = 0.05; // 5%
        Time maturity = 0.25;      // 3 months
        double volatility = 0.20; // 20%
        std::cout << "Time to maturity = "        << maturity
                  << std::endl;
        std::cout << "Underlying price = "        << underlying
                  << std::endl;
        std::cout << "Strike = "                  << strike
                  << std::endl;
        std::cout << "Risk-free interest rate = " << riskFreeRate
                  << std::endl;
```

```
std::cout << "Volatility = "              << volatility
          << std::endl;
std::cout << std::endl;

// write column headings
std::cout << "Method\t\tValue\tEstimatedError\tDiscrepancy"
    "\tRel. Discr." << std::endl;



// first method: Black Scholes analytic solution
std::string method ="Black Scholes";
double value = EuropeanOption(Option::Call, underlying, strike,
    dividendYield, riskFreeRate, maturity, volatility).value();
double estimatedError = 0.0;
double discrepancy = 0.0;
double relativeDiscrepancy = 0.0;
std::cout << method << "\t"
     << DoubleFormatter::toString(value, 4) << "\t"
     << DoubleFormatter::toString(estimatedError, 4) << "\t\t"
     << DoubleFormatter::toString(discrepancy, 6) << "\t"
     << DoubleFormatter::toString(relativeDiscrepancy, 6)
     << std::endl;


// store the Black Scholes value as the correct one
double rightValue = value;




// second method: Call-Put parity
method ="Call-Put parity";
value = EuropeanOption(Option::Put, underlying, strike,
    dividendYield, riskFreeRate, maturity, volatility).value()
    + underlying - strike*QL_EXP(- riskFreeRate*maturity);
discrepancy = QL_FABS(value-rightValue);
relativeDiscrepancy = discrepancy/rightValue;
std::cout << method << "\t"
     << DoubleFormatter::toString(value, 4) << "\t"
     << "N/A\t\t"
     << discrepancy << "\t"
     << DoubleFormatter::toString(relativeDiscrepancy, 6)
     << std::endl;


// third method: Integral
method ="Integral";
using QuantLib::Math::SegmentIntegral;
Payoff po(maturity, strike, underlying, volatility, riskFreeRate);
SegmentIntegral integrator(5000);

double nuT = (riskFreeRate - 0.5*volatility*volatility)*maturity;
double infinity = 10.0*volatility*QL_SQRT(maturity);

value = integrator(po, nuT-infinity, nuT+infinity);
discrepancy = QL_FABS(value-rightValue);
relativeDiscrepancy = discrepancy/rightValue;
std::cout << method << "\t"
     << DoubleFormatter::toString(value, 4) << "\t"
     << "N/A\t\t"
     << DoubleFormatter::toString(discrepancy, 6) << "\t"
     << DoubleFormatter::toString(relativeDiscrepancy, 6)
     << std::endl;
```

```
    // fourth method: Finite Differences
    method ="Finite Diff.";
    Size grid = 100;
    value = FdEuropean(Option::Call, underlying, strike,
        dividendYield, riskFreeRate, maturity, volatility, grid).value();
    discrepancy = QL_FABS(value-rightValue);
    relativeDiscrepancy = discrepancy/rightValue;
    std::cout << method << "\t"
         << DoubleFormatter::toString(value, 4) << "\t"
         << "N/A\t\t"
         << DoubleFormatter::toString(discrepancy, 6) << "\t"
         << DoubleFormatter::toString(relativeDiscrepancy, 6)
         << std::endl;



    // fifth method: Monte Carlo (crude)
    method ="MC (crude)";
    bool antitheticVariance = false;
    McEuropean mcEur(Option::Call, underlying, strike, dividendYield,
        riskFreeRate, maturity, volatility, antitheticVariance);
    // let's require a tolerance of 0.002%
    value = mcEur.value(0.002);
    estimatedError = mcEur.errorEstimate();
    discrepancy = QL_FABS(value-rightValue);
    relativeDiscrepancy = discrepancy/rightValue;
    std::cout << method << "\t"
         << DoubleFormatter::toString(value, 4) << "\t"
         << DoubleFormatter::toString(estimatedError, 4) << "\t\t"
         << DoubleFormatter::toString(discrepancy, 6) << "\t"
         << DoubleFormatter::toString(relativeDiscrepancy, 6)
         << std::endl;

    // sixth method: Monte Carlo with antithetic variance reduction
    method ="MC (antithetic)";
    // let's use the same number of samples as in the crude Monte Carlo
    Size nSamples = mcEur.sampleAccumulator().samples();
    antitheticVariance = true;
    McEuropean mcEur2(Option::Call, underlying, strike, dividendYield,
        riskFreeRate, maturity, volatility, antitheticVariance);
    value = mcEur2.valueWithSamples(nSamples);
    estimatedError = mcEur2.errorEstimate();
    discrepancy = QL_FABS(value-rightValue);
    relativeDiscrepancy = discrepancy/rightValue;
    std::cout << method << "\t"
         << DoubleFormatter::toString(value, 4) << "\t"
         << DoubleFormatter::toString(estimatedError, 4) << "\t\t"
         << DoubleFormatter::toString(discrepancy, 6) << "\t"
         << DoubleFormatter::toString(relativeDiscrepancy, 6)
         << std::endl;


    return 0;
} catch (std::exception& e) {
    std::cout << e.what() << std::endl;
    return 1;
} catch (...) {
    std::cout << "unknown error" << std::endl;
    return 1;
}
```

```
}
```

13.3 history_iterators.cpp

This code exemplifies how to use History iterators to perform statistic analyses on historical data.

```
// initialize a History
History h(...);

// print out the mean value and its standard deviation.

Statistics s;
s.addSequence(h.vdbegin(),h.vdend());
cout << "Historical mean: " << s.mean() << endl;
cout << "Std. deviation:  " << s.standardDeviation() << endl;

// Another possibility: print out the maximum value.

History::const_valid_iterator max = h.vbegin(), i=max, end = h.vend();
for (i++; i!=end; i++)
    if (i->value() > max->value())
        max = i;
cout << "Maximum value: " << max->value()
     << " assumed " << DateFormatter::toString(max->date()) << endl;

// or the minimum, this time the STL way:

bool lessthan(const History::Entry& i, const History::Entry& j) {
    return i.value() < j.value();
}

History::const_valid_iterator min =
    std::min_element(h.vbegin(),h.vend(),lessthan);
cout << "Minimum value: " << min->value()
     << " assumed " << DateFormatter::toString(min->date()) << endl;
```

13.4 swapvaluation.cpp

This is an example of using the QuantLib Term Structure for pricing a simple swap.

```
/*  This example shows how to set up a Term Structure and then price a simple
    swap.
*/

// the only header you need to use QuantLib
#include <ql/quantlib.hpp>


using namespace QuantLib;
using Calendars::TARGET;
using DayCounters::ActualActual;
using DayCounters::Actual360;
using DayCounters::Thirty360;
using Indexes::Xibor;
using Indexes::Euribor;
using Instruments::SimpleSwap;
using TermStructures::PiecewiseFlatForward;
using TermStructures::FlatForward;
using TermStructures::RateHelper;
using TermStructures::DepositRateHelper;
using TermStructures::FraRateHelper;
using TermStructures::FuturesRateHelper;
using TermStructures::SwapRateHelper;


int main(int argc, char* argv[])
{
    try {
        Calendar calendar = TARGET();
        Currency currency = EUR;
        int settlementDays = 2;
        int fixingDays = 2;

        /*********************
         ***  MARKET DATA  ***
         *********************/

        Date todaysDate(6, November, 2001);

        // deposits
        double d1wQuote=0.0382;
        double d1mQuote=0.0372;
        double d3mQuote=0.0363;
        double d6mQuote=0.0353;
        double d9mQuote=0.0348;
        double d1yQuote=0.0345;
        // FRAs
        double fra3x6Quote=0.037125;
        double fra6x9Quote=0.037125;
        double fra6x12Quote=0.037125;
        // futures
        double fut1Quote=96.2875;
        double fut2Quote=96.7875;
        double fut3Quote=96.9875;
        double fut4Quote=96.6875;
        double fut5Quote=96.4875;
        double fut6Quote=96.3875;
        double fut7Quote=96.2875;
```

```
double fut8Quote=96.0875;
// swaps
double s2yQuote=0.037125;
double s3yQuote=0.0398;
double s5yQuote=0.0443;
double s10yQuote=0.05165;
double s15yQuote=0.055175;



/*********************
 ***  RATE HELPERS ***
 *********************/

// RateHelpers are built from the above quotes together with other
// instrument dependant infos.

// setup deposits
DayCounter depositDayCounter = Actual360();

Handle<RateHelper> d1w(new DepositRateHelper(
    d1wQuote, settlementDays,
    1, Weeks, calendar, ModifiedFollowing, depositDayCounter));
Handle<RateHelper> d1m(new DepositRateHelper(
    d1mQuote, settlementDays,
    1, Months, calendar, ModifiedFollowing, depositDayCounter));
Handle<RateHelper> d3m(new DepositRateHelper(
    d3mQuote, settlementDays,
    3, Months, calendar, ModifiedFollowing, depositDayCounter));
Handle<RateHelper> d6m(new DepositRateHelper(
    d6mQuote, settlementDays,
    6, Months, calendar, ModifiedFollowing, depositDayCounter));
Handle<RateHelper> d9m(new DepositRateHelper(
    d9mQuote, settlementDays,
    9, Months, calendar, ModifiedFollowing, depositDayCounter));
Handle<RateHelper> d1y(new DepositRateHelper(
    d1yQuote, settlementDays,
    1, Years, calendar, ModifiedFollowing, depositDayCounter));

// setup swaps
int swFixedLegFrequency = 1;
bool swFixedLegIsAdjusted = false;
DayCounter swFixedLegDayCounter = Thirty360(Thirty360::European);
int swFloatingLegFrequency = 2;

Handle<RateHelper> s2y(new SwapRateHelper(
    s2yQuote, settlementDays,
    2, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
Handle<RateHelper> s3y(new SwapRateHelper(
    s3yQuote, settlementDays,
    3, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
Handle<RateHelper> s5y(new SwapRateHelper(
    s5yQuote, settlementDays,
    5, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
Handle<RateHelper> s10y(new SwapRateHelper(
    s10yQuote, settlementDays,
    10, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
```

```
    swFloatingLegFrequency));
Handle<RateHelper> s15y(new SwapRateHelper(
    s15yQuote, settlementDays,
    15, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));


/*********************
 **  CURVE BUILDING **
 *********************/

// Any DayCounter would be fine.
// ActualActual::ISDA ensures that 30 years is 30.0
DayCounter termStructureDayCounter =
    ActualActual(ActualActual::ISDA);

// A depo-swap curve
std::vector<Handle<RateHelper> > depoSwapInstruments;
depoSwapInstruments.push_back(d1w);
depoSwapInstruments.push_back(d1m);
depoSwapInstruments.push_back(d3m);
depoSwapInstruments.push_back(d6m);
depoSwapInstruments.push_back(d9m);
depoSwapInstruments.push_back(d1y);
depoSwapInstruments.push_back(s2y);
depoSwapInstruments.push_back(s3y);
depoSwapInstruments.push_back(s5y);
depoSwapInstruments.push_back(s10y);
depoSwapInstruments.push_back(s15y);
Handle<TermStructure> depoSwapTermStructure(new
    PiecewiseFlatForward(currency, termStructureDayCounter,
    todaysDate, calendar, settlementDays, depoSwapInstruments));


 /*********************
 * SWAPS TO BE PRICED *
 *********************/

// Term structures that will be used for pricing:
// the one used for discounting cash flows
RelinkableHandle<TermStructure> discountingTermStructure;
// the one used for forward rate forecasting
RelinkableHandle<TermStructure> forecastingTermStructure;


// spot start
Date spotDate = calendar.advance(todaysDate, settlementDays, Days,
    Following);
// constant nominal 1,000,000 Euro
double nominal = 1000000.0;
// fixed leg
int fixedLegFrequency = 1; // annual
bool fixedLegIsAdjusted = false;
RollingConvention roll = ModifiedFollowing;
DayCounter fixedLegDayCounter = Thirty360(Thirty360::European);
Rate fixedRate = 0.04;

// floating leg
int floatingLegFrequency = 2;
Handle<Xibor> euriborIndex(new Euribor(6, Months,
    forecastingTermStructure)); // using the forecasting curve
Spread spread = 0.0;

int lenghtInYears = 5;
```

```
bool payFixedRate = true;
SimpleSwap spot5YearSwap(payFixedRate, spotDate, lenghtInYears,
    Years, calendar, roll, nominal, fixedLegFrequency, fixedRate,
    fixedLegIsAdjusted, fixedLegDayCounter, floatingLegFrequency,
    euriborIndex, fixingDays, spread,
    discountingTermStructure); // using the discounting curve
SimpleSwap oneYearForward5YearSwap(payFixedRate,
    calendar.advance(spotDate, 1, Years, ModifiedFollowing),
    lenghtInYears, Years,
    calendar, roll, nominal, fixedLegFrequency, fixedRate,
    fixedLegIsAdjusted, fixedLegDayCounter, floatingLegFrequency,
    euriborIndex, fixingDays, spread,
    discountingTermStructure); // using the discounting curve



 /***************
 * SWAP PRICING *
 ****************/

// let's price in term of NPV, fixed rate, and spread
double NPV;
Rate fairFixedRate;
Spread fairFloatingSpread;

// Of course, you're not forced to really use different curves
forecastingTermStructure.linkTo(depoSwapTermStructure);
discountingTermStructure.linkTo(depoSwapTermStructure);
std::cout << "*** using Depo-Fut-Swap term structure:" << std::endl;

NPV = spot5YearSwap.NPV();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:               "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = - NPV / spot5YearSwap.floatingLegBPS();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:              "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV / spot5YearSwap.fixedLegBPS();
std::cout << "5Y fixed rate:                  "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;
// let's check that the 5 years swap has been correctly re-priced
QL_REQUIRE(QL_FABS(fairFixedRate-s5yQuote)<1e-8,
    "5 years swap mispriced!");

// now let's price the 1Y forward 5Y swap
NPV = oneYearForward5YearSwap.NPV();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:            "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = -NPV / spot5YearSwap.floatingLegBPS();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:           "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV/oneYearForward5YearSwap.fixedLegBPS();
std::cout << "1Yx5Y fixed rate:               "
```

```
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;




// now, let's get serious

/*********************
 ***  MARKET DATA  ***
 *********************/

// market elements are containers for quotes.
// SimpleMarketElement stores a value which can be manually changed;
// other MarketElement subclasses could read the value from a
// database or some kind of data feed.

// deposits
Handle<MarketElement> d1wRate(new SimpleMarketElement(d1wQuote));
Handle<MarketElement> d1mRate(new SimpleMarketElement(d1mQuote));
Handle<MarketElement> d3mRate(new SimpleMarketElement(d3mQuote));
Handle<MarketElement> d6mRate(new SimpleMarketElement(d6mQuote));
Handle<MarketElement> d9mRate(new SimpleMarketElement(d9mQuote));
Handle<MarketElement> d1yRate(new SimpleMarketElement(d1yQuote));
// FRAs
Handle<MarketElement> fra3x6Rate(new SimpleMarketElement(fra3x6Quote));
Handle<MarketElement> fra6x9Rate(new SimpleMarketElement(fra6x9Quote));
Handle<MarketElement> fra6x12Rate(new SimpleMarketElement(fra6x12Quote));
// futures
Handle<MarketElement> fut1Price(new SimpleMarketElement(fut1Quote));
Handle<MarketElement> fut2Price(new SimpleMarketElement(fut2Quote));
Handle<MarketElement> fut3Price(new SimpleMarketElement(fut3Quote));
Handle<MarketElement> fut4Price(new SimpleMarketElement(fut4Quote));
Handle<MarketElement> fut5Price(new SimpleMarketElement(fut5Quote));
Handle<MarketElement> fut6Price(new SimpleMarketElement(fut6Quote));
Handle<MarketElement> fut7Price(new SimpleMarketElement(fut7Quote));
Handle<MarketElement> fut8Price(new SimpleMarketElement(fut8Quote));
// swaps
Handle<MarketElement> s2yRate(new SimpleMarketElement(s2yQuote));
Handle<MarketElement> s3yRate(new SimpleMarketElement(s3yQuote));
Handle<MarketElement> s5yRate(new SimpleMarketElement(s5yQuote));
Handle<MarketElement> s10yRate(new SimpleMarketElement(s10yQuote));
Handle<MarketElement> s15yRate(new SimpleMarketElement(s15yQuote));




/*********************
 ***  RATE HELPERS ***
 *********************/

// RateHelpers are built from the above quotes together with other
// instrument dependant infos.
// This time quotes are passed in relinkable
// handles which could be relinked to some other data source later.

// setup deposits
d1w =Handle<RateHelper>(new DepositRateHelper(
    RelinkableHandle<MarketElement>(d1wRate), settlementDays,
    1, Weeks, calendar, ModifiedFollowing, depositDayCounter));
d1m=Handle<RateHelper>(new DepositRateHelper(
```

```
    RelinkableHandle<MarketElement>(d1mRate), settlementDays,
    1, Months, calendar, ModifiedFollowing, depositDayCounter));
d3m=Handle<RateHelper>(new DepositRateHelper(
    RelinkableHandle<MarketElement>(d3mRate), settlementDays,
    3, Months, calendar, ModifiedFollowing, depositDayCounter));
d6m=Handle<RateHelper>(new DepositRateHelper(
    RelinkableHandle<MarketElement>(d6mRate), settlementDays,
    6, Months, calendar, ModifiedFollowing, depositDayCounter));
d9m=Handle<RateHelper>(new DepositRateHelper(
    RelinkableHandle<MarketElement>(d9mRate), settlementDays,
    9, Months, calendar, ModifiedFollowing, depositDayCounter));
d1y=Handle<RateHelper>(new DepositRateHelper(
    RelinkableHandle<MarketElement>(d1yRate), settlementDays,
    1, Years, calendar, ModifiedFollowing, depositDayCounter));

// setup swaps
s2y=Handle<RateHelper>(new SwapRateHelper(
    RelinkableHandle<MarketElement>(s2yRate), settlementDays,
    2, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
s3y=Handle<RateHelper>(new SwapRateHelper(
    RelinkableHandle<MarketElement>(s3yRate), settlementDays,
    3, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
s5y=Handle<RateHelper>(new SwapRateHelper(
    RelinkableHandle<MarketElement>(s5yRate), settlementDays,
    5, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
s10y=Handle<RateHelper>(new SwapRateHelper(
    RelinkableHandle<MarketElement>(s10yRate), settlementDays,
    10, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));
s15y=Handle<RateHelper>(new SwapRateHelper(
    RelinkableHandle<MarketElement>(s15yRate), settlementDays,
    15, calendar, ModifiedFollowing, swFixedLegFrequency,
    swFixedLegIsAdjusted, swFixedLegDayCounter,
    swFloatingLegFrequency));


// let's add FRA and futures

// setup FRAs
Handle<RateHelper> fra3x6(new FraRateHelper(
    RelinkableHandle<MarketElement>(fra3x6Rate),
    settlementDays, 3, 6, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fra6x9(new FraRateHelper(
    RelinkableHandle<MarketElement>(fra6x9Rate),
    settlementDays, 6, 9, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fra6x12(new FraRateHelper(
    RelinkableHandle<MarketElement>(fra6x12Rate),
    settlementDays, 6, 12, calendar, ModifiedFollowing,
    depositDayCounter));

// setup futures
int futMonths = 3;
Handle<RateHelper> fut1(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(19, December, 2001),
    settlementDays, futMonths, calendar, ModifiedFollowing,
```

```
    depositDayCounter));
Handle<RateHelper> fut2(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(20, March, 2002),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut3(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(19, June, 2002),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut4(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(18, September, 2002),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut5(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(18, December, 2002),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut6(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(19, March, 2003),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut7(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(18, June, 2003),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));
Handle<RateHelper> fut8(new FuturesRateHelper(
    RelinkableHandle<MarketElement>(fut1Price),
    Date(17, September, 2003),
    settlementDays, futMonths, calendar, ModifiedFollowing,
    depositDayCounter));




/*********************
 **  CURVE BUILDING **
 *********************/

// A depo-futures-swap curve
std::vector<Handle<RateHelper> > depoFutSwapInstruments;
depoFutSwapInstruments.push_back(d1w);
depoFutSwapInstruments.push_back(d1m);
depoFutSwapInstruments.push_back(fut1);
depoFutSwapInstruments.push_back(fut2);
depoFutSwapInstruments.push_back(fut3);
depoFutSwapInstruments.push_back(fut4);
depoFutSwapInstruments.push_back(fut5);
depoFutSwapInstruments.push_back(fut6);
depoFutSwapInstruments.push_back(fut7);
depoFutSwapInstruments.push_back(fut8);
depoFutSwapInstruments.push_back(s3y);
depoFutSwapInstruments.push_back(s5y);
depoFutSwapInstruments.push_back(s10y);
depoFutSwapInstruments.push_back(s15y);
Handle<TermStructure> depoFutSwapTermStructure(new
    PiecewiseFlatForward(currency, termStructureDayCounter,
    todaysDate, calendar, settlementDays, depoFutSwapInstruments));
```

```
// A depo-FRA-swap curve
std::vector<Handle<RateHelper> > depoFRASwapInstruments;
depoFRASwapInstruments.push_back(d1w);
depoFRASwapInstruments.push_back(d1m);
depoFRASwapInstruments.push_back(d3m);
depoFRASwapInstruments.push_back(fra3x6);
depoFRASwapInstruments.push_back(fra6x9);
depoFRASwapInstruments.push_back(fra6x12);
depoFRASwapInstruments.push_back(s2y);
depoFRASwapInstruments.push_back(s3y);
depoFRASwapInstruments.push_back(s5y);
depoFRASwapInstruments.push_back(s10y);
depoFRASwapInstruments.push_back(s15y);
Handle<TermStructure> depoFRASwapTermStructure(new
    PiecewiseFlatForward(currency, termStructureDayCounter,
    todaysDate, calendar, settlementDays, depoFRASwapInstruments));




 /***************
 * SWAP PRICING *
 ***************/


// switch the curve used by the swaps to be priced
forecastingTermStructure.linkTo(depoFutSwapTermStructure);
discountingTermStructure.linkTo(depoFutSwapTermStructure);
std::cout << "*** using Depo-Fut-Swap term structure:" << std::endl;

NPV = spot5YearSwap.NPV();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:               "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = - NPV / spot5YearSwap.floatingLegBPS();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:               "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV / spot5YearSwap.fixedLegBPS();
std::cout << "5Y fixed rate:                  "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;
// let's check that the 5 years swap has been correctly re-priced
QL_REQUIRE(QL_FABS(fairFixedRate-s5yQuote)<1e-8,
    "5 years swap mispriced!");

// now let's price the 1Y forward 5Y swap
NPV = oneYearForward5YearSwap.NPV();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:            "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = -NPV / spot5YearSwap.floatingLegBPS();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
```

```
    << " spread:            "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV/oneYearForward5YearSwap.fixedLegBPS();
std::cout << "1Yx5Y fixed rate:               "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;


// switch the curve used by the swaps to be priced
forecastingTermStructure.linkTo(depoFRASwapTermStructure);
discountingTermStructure.linkTo(depoFRASwapTermStructure);
std::cout << "*** using Depo-FRA-Swap term structure:" << std::endl;

NPV = spot5YearSwap.NPV();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:               "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = - NPV / spot5YearSwap.floatingLegBPS();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:                "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV / spot5YearSwap.fixedLegBPS();
std::cout << "5Y fixed rate:                  "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;
// let's check that the 5 years swap has been correctly re-priced
QL_REQUIRE(QL_FABS(fairFixedRate-s5yRate->value())<1e-8,
    "5 years swap mispriced!");

// now let's price the 1Y forward 5Y swap
NPV = oneYearForward5YearSwap.NPV();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:            "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = -NPV / spot5YearSwap.floatingLegBPS();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:            "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV/oneYearForward5YearSwap.fixedLegBPS();
std::cout << "1Yx5Y fixed rate:               "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;


// now let's say that the 5-years swap rate goes up to 4.60%.
// A smarter market element--say, connected to a data source-- would
// notice the change itself. Since we're using SimpleMarketElements,
// we'll have to change the value manually--which forces us to
// downcast the handle and use the SimpleMarketElement
// interface. In any case, the point here is that a change in the
// value contained in the MarketElement triggers a new bootstrapping
// of the curve and a repricing of the swap.

Handle<SimpleMarketElement> fiveYearsRate = s5yRate;
fiveYearsRate->setValue(0.0460);
std::cout <<  "*** 5Y swap goes up to 4.60%" << std::endl;
```

```
// now get the updated results
forecastingTermStructure.linkTo(depoFutSwapTermStructure);
discountingTermStructure.linkTo(depoFutSwapTermStructure);
std::cout << "*** using Depo-Fut-Swap term structure:" << std::endl;

NPV = spot5YearSwap.NPV();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:               "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = - NPV / spot5YearSwap.floatingLegBPS();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:               "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV / spot5YearSwap.fixedLegBPS();
std::cout << "5Y fixed rate:                  "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;
// let's check that the 5 years swap has been correctly re-priced
QL_REQUIRE(QL_FABS(fairFixedRate-s5yRate->value())<1e-8,
    "5 years swap mispriced!");

NPV = oneYearForward5YearSwap.NPV();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:            "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = -NPV / spot5YearSwap.floatingLegBPS();
std::cout << "1Yx5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:            "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV/oneYearForward5YearSwap.fixedLegBPS();
std::cout << "1Yx5Y fixed rate:               "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;


forecastingTermStructure.linkTo(depoFRASwapTermStructure);
discountingTermStructure.linkTo(depoFRASwapTermStructure);
std::cout << "*** using Depo-FRA-Swap term structure:" << std::endl;

NPV = spot5YearSwap.NPV();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " NPV:               "
    << DoubleFormatter::toString(NPV,2)
    << std::endl;
fairFloatingSpread = - NPV / spot5YearSwap.floatingLegBPS();
std::cout << "5Y "
    << RateFormatter::toString(fixedRate,2)
    << " spread:               "
    << RateFormatter::toString(fairFloatingSpread,8)
    << std::endl;
fairFixedRate = fixedRate - NPV / spot5YearSwap.fixedLegBPS();
std::cout << "5Y fixed rate:                  "
    << RateFormatter::toString(fairFixedRate,8)
    << std::endl;
```

```
        // let's check that the 5 years swap has been correctly re-priced
        QL_REQUIRE(QL_FABS(fairFixedRate-s5yRate->value())<1e-8,
            "5 years swap mispriced!");

        NPV = oneYearForward5YearSwap.NPV();
        std::cout << "1Yx5Y "
            << RateFormatter::toString(fixedRate,2)
            << " NPV:            "
            << DoubleFormatter::toString(NPV,2)
            << std::endl;
        fairFloatingSpread = -NPV / spot5YearSwap.floatingLegBPS();
        std::cout << "1Yx5Y "
            << RateFormatter::toString(fixedRate,2)
            << " spread:           "
            << RateFormatter::toString(fairFloatingSpread,8)
            << std::endl;
        fairFixedRate = fixedRate - NPV/oneYearForward5YearSwap.fixedLegBPS();
        std::cout << "1Yx5Y fixed rate:              "
            << RateFormatter::toString(fairFixedRate,8)
            << std::endl;


        return 0;

    } catch (std::exception& e) {
        std::cout << e.what() << std::endl;
        return 1;
    } catch (...) {
        std::cout << "unknown error" << std::endl;
        return 1;
    }
}
```

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