Package 'MVNGmod'

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Type Package

Title Matrix-Variate Non-Gaussian Linear Regression Models

Version 0.1.2

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Description Fits matrix-variate variance-gamma (MVVG) and matrix-variate normal-inverse-Gaussian (MVNIG) linear regression models using expectation-conditional maximization (ECM) algorithms. The models accommodate clustered matrix-valued responses, with unequal numbers of observations across subjects, correlated responses, skewness, and within-subject dependence. Functions are provided for model fitting, prediction, and subject-level influence assessment using approximate generalized Cook's distances. The package also includes motivating periodontal data from Gullah-speaking African Americans with Type-II diabetes. For details on the underlying matrix-variate distributions (MVVG and MVNIG), see Gallaugher and McNicholas (2019, <doi:10.1016/j.spl.2018.08.012>).

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Encoding UTF-8

LazyData true

RoxygenNote 7.3.3

Imports Bessel, clusterGeneration, DistributionUtils, matlib, maxLik, truncnorm, pracma, matrixcalc, purrr

URL https://github.com/soonsk-vcu/MVNGmod

BugReports https://github.com/soonsk-vcu/MVNGmod/issues

Suggests knitr, rmarkdown

VignetteBuilder knitr

NeedsCompilation no

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Depends R (>= 3.5.0)

Repository CRAN

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Contents

`case_del` *Case Deletion for MVNG Models*

Description

This function calculates influence statistics for each element of the data list using a one-step approximation to the generalized Cook's distance.

Usage

```
case_del(Y, X, mod)
```

Arguments

`Y`	List of $n_i \times p$ response matrices. Matrices must have same number of columns.
`X`	List of $n_i \times q$ design matrices. Matrices must have same number of columns.
`mod`	Model object returned by a call to `MVVGmod` or `MVNIGmod`.

Details

Computes influence statistics for the MVVG and MVNIG models using a one-step approximation to the generalized Cook's distance, based on the score and hessian matrices of the complete-data log-likelihood.

$$GD_i^1(\theta) = \dot{Q}_{[i]}(\hat{\theta}|\hat{\theta})^T[-\ddot{Q}(\hat{\theta}|\hat{\theta})]^{-1}\dot{Q}_{[i]}(\hat{\theta}|\hat{\theta}),$$

where

$$\dot{Q}_{[i]}(\hat{\theta}|\hat{\theta}) = \frac{\partial Q_{[i]}(\theta|\hat{\theta})}{\partial\theta}|_{\theta=\hat{\theta}}$$

is the complete-data score function with the ith subject deleted and evaluated in $\hat{\theta}$, and

$$\ddot{Q}(\hat{\theta}|\hat{\theta}) = \frac{\partial^2 Q(\theta|\hat{\theta})}{\partial\theta\partial\theta^T}|_{\theta=\hat{\theta}}$$

is the complete-data Hessian matrix, as given in Lachos *et al.* (2015) doi:10.1016/j.jmva.2015.06.014

Value

case_del returns a vector containing the approximate generalized Cook's distance for each corresponding subject in the provided dataset.

Author(s)

Samuel Soon

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Examples

```
mod <- MVNIGmod(Y,X,theta_mvnig)
case_del(Y,X,mod)
```

---

gaad_cov *GAAD Data*

Description

These data sets describe periodontal measurements performed on members of the Gullah-Speaking African American community.

Usage

```
gaad_cov
```

Format

Each is a list of matrices, with rows denoting tooth sites and columns denoting CAL/PPD response.

Details

gaad_res and gaad_cov contain the response and covariate matrices of the GAAD data.

Examples

```
gaad_cov
gaad_res
```

gaad_res *GAAD Data*

Description

These data sets describe periodontal measurements performed on members of the Gullah-Speaking African American community.

Usage

```
gaad_res
```

Format

Each is a list of matrices, with rows denoting tooth sites and columns denoting CAL/PPD response.

Details

`gaad_res` and `gaad_cov` contain the response and covariate matrices of the GAAD data.

Examples

```
gaad_cov
gaad_res
```

gaad_theta_mvvg *MVVG Parameter Format*

Description

This is an example of the format of input parameter list theta.

Usage

```
gaad_theta_mvvg
```

Format

List of model parameters.

Examples

```
gaad_theta_mvvg
```

MVNIGmod *ECM Estimation for Matrix-Variate Normal-Inverse Gaussian Models*

Description

This function fits MVNIG linear models for matrix-variate skew data with non-uniform data rows between subjects. Exchangeable observation row correlation and skewness structures are imposed to accommodate the varying row counts across matrices. Note that multiple restarts may be needed to account for unstable local maxima.

Usage

```
MVNIGmod(Y, X, theta_g = NULL, stopping = 0.001, max_iter = 50)
```

Arguments

Y	List of $n_i \times p$ response matrices. Matrices must have same number of columns.
X	List of $n_i \times q$ design matrices. Matrices must have same number of columns.
theta_g	List of parameters to pass as initial values in the ECM algorithm. If NULL, will be randomly generated. See Details for an in-depth explanation.
stopping	Stopping threshold for the L-infinity norm of differences in consecutive parameter space, evaluated at iteration $t+1$ as $\|\hat{\theta}^{t+1} - \hat{\theta}^{t}\|_{\infty}$. Default is 0.001
max_iter	Maximum number of iterations, default is 50.

Details

Fits the matrix-variate skew regression model

$$Y_i = X_i\Theta + E_i,$$

where each response Y_i is a $n_i \times p$ matrix that indexes n_i observations and p response variables. X_i corresponds to a $n_i \times q$ design matrix, and Θ corresponds to a $q \times p$ coefficient matrix. E_i corresponds to a $n_i \times p$ error matrix, following a matrix-variate variance-gamma distribution.

The model estimates MVVG parameters $\Theta, \underline{a}, r, \Psi, \tilde{\gamma}$ using the alternating expectation conditional maximization (ECM) algorithm, using the density

$$f(Y_i|M_i,\underline{a},r,\Psi,\tilde{\gamma},n_i,p) = \frac{2\exp[tr(\Sigma_i^{-1}(Y_i-M_i)\Psi^{-1}A_i^T)+\tilde{\gamma}]}{(2\pi)^{\frac{n_ip}{2}+1}|\Sigma_i|^{\frac{p}{2}}|\Psi|^{\frac{n_i}{2}}}\left(\frac{\delta(Y_i;M_i,\Sigma_i,\Psi)+1}{\rho(A_i,\Sigma_i,\Psi)+\tilde{\gamma}^2}\right)^{-\frac{(1+n_ip)}{4}} \times K_{-\frac{(1+n_ip)}{2}}\left(\sqrt{[\rho(A_i\right.}$$

where $A_i = \underline{1}_{n_i} \times \underline{a}^T$, $\Sigma_i = I_{n_i} + r(\underline{1}_{n_i}\underline{1}_{n_i}^T - I_{n_i})$, $\delta(X;M,\Sigma,\Psi) = matlib :: tr(\Sigma^{-1}(X - M)\Psi^{-1}(X-M)^T)$, $\rho(A,\Sigma,\Psi) = matlib :: tr(\Sigma^{-1}A\Psi^{-1}A^T)$, and $K_\nu(x)$ is the modified Bessel function of the second kind.

The structure of theta_g and parameter estimates returned by the function must be in the form of a list with the following named elements:

`Theta`: $q \times p$ coefficient matrix

`a`: $p \times 1$ skewness vector

`rho`: Compound symmetry parameter for row correlation matrix

`Psi`: $p \times p$ column covariance matrix

`tgamma`: Univariate mixing parameter

Value

`MVNIGmod` returns a list with the following elements:

`Iteration`: Number of iterations taken to convergence. `Inf` if convergence not reached.

`Starting Value`: List of initial parameter values.

`Final Value`: List of final parameter estimates.

`Stopping Criteria`: Vector of $|\hat{\theta}^{t+1} - \hat{\theta}^{t}|_{\infty}$ at each iteration.

`AIC`: Model AIC

`BIC`: Model BIC

Author(s)

Samuel Soon

Dipankar Bandyopadhyay

Qingyang Liu

Examples

```
MVNIGmod(Y,X,theta_mvnig)
```

`MVVGmod` *ECM Estimation for Matrix-Variate Variance Gamma (MVVG) Models*

Description

This function fits MVVG linear models for matrix-variate skew data with non-uniform data rows between subjects. Exchangeable observation row correlation and skewness structures are imposed to accommodate the varying row counts across matrices. Note that multiple restarts may be needed to account for unstable local maxima.

Usage

```
MVVGmod(Y, X, theta_g = NULL, stopping = 0.001, max_iter = 50)
```

Arguments

Y	List of $n_i \times p$ response matrices. Matrices must have same number of columns.
X	List of $n_i \times q$ design matrices. Matrices must have same number of columns.
theta_g	List of parameters to pass as initial values in the ECM algorithm. If NULL, will be randomly generated. See Details for an in-depth explanation.
stopping	Stopping threshold for the L-infinity norm of differences in consecutive parameter space, evaluated at iteration $t+1$ as $\|\hat{\theta}^{t+1} - \hat{\theta}^t\|_\infty$. Default is 0.001
max_iter	Maximum number of iterations, default is 50.

Details

Fits the matrix-variate skew regression model

$$Y_i = X_i\Theta + E_i,$$

where each response Y_i is a $n_i \times p$ matrix that indexes n_i observations and p response variables. X_i corresponds to a $n_i \times q$ design matrix, and Θ corresponds to a $q \times p$ coefficient matrix. E_i corresponds to a $n_i \times p$ error matrix, following a matrix-variate variance-gamma distribution.

The model estimates MVVG parameters $\Theta, \underline{a}, r, \Psi, \gamma$ using the alternating expectation conditional maximization (ECM) algorithm, using the density

$$f(Y_i|X_i\Theta, \underline{a}, r, \Psi, \gamma, n_i, p) = \frac{2\gamma^\gamma \exp[tr(\Sigma_i^{-1}(Y_i - X_i\Theta)\Psi^{-1}A_i^T)]}{(2\pi)^{n_ip/2}|\Sigma_i|^{p/2}|\Psi|^{n_i/2}\Gamma(\gamma)}\left(\frac{\delta(Y_i; X_i\Theta, \Sigma_i, \Psi)}{\rho(A_i, \Sigma_i, \Psi) + 2\gamma}\right)^{(\gamma - n_ip/2)/2} \times K_{(\gamma - n_ip/2)}\left(\sqrt{[\rho($$

where $A_i = \underline{1}_{n_i} \times \underline{a}^T$, $\Sigma_i = I_{n_i} + r(\underline{1}_{n_i}\underline{1}_{n_i}^T - I_{n_i})$, $\delta(X; M, \Sigma, \Psi) = matlib :: tr(\Sigma^{-1}(X - M)\Psi^{-1}(X-M)^T)$, $\rho(A, \Sigma, \Psi) = matlib :: tr(\Sigma^{-1}A\Psi^{-1}A^T)$, and $K_\nu(x)$ is the modified Bessel function of the second kind.

The structure of theta_g and parameter estimates returned by the function must be in the form of a list with the following named elements:

Theta: $q \times p$ coefficient matrix

a: $p \times 1$ skewness vector

rho: Compound symmetry parameter for row correlation matrix

Psi: $p \times p$ column covariance matrix

gamma: Univariate mixing parameter

Value

MVVGmod returns a list with the following elements:

Iteration: Number of iterations taken to convergence. Inf if convergence not reached.

Starting Value: List of initial parameter values.

Final Value: List of final parameter estimates.

Stopping Criteria: Vector of $|\hat{\theta}^{t+1} - \hat{\theta}^t|_\infty$ at each iteration.

AIC: Model AIC

BIC: Model BIC

Author(s)

Samuel Soon

Dipankar Bandyopadhyay

Qingyang Liu

Examples

```
MVVGmod(Y,X,theta_mvvg)
```

---

predict *MVNG Model Prediction*

Description

Predicts response values given a list of covariate matrices and a model output from either MVVGmod or MVNIGmod.

Usage

```
predict(mod, X)
```

Arguments

mod	object outputted by either MVVGmod or MVNIGmod
X	Inputted covariate matrix

Value

Returns a list of predicted response matrices

Author(s)

Samuel Soon

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Qingyang Liu

Examples

```
set.seed(1234)
mvnig_mod <- MVNIGmod(Y,X,theta_mvnig)

predict(mvnig_mod,X)
```

theta_mvnig *Toy Response Initial Parameter (MVNIG)*

Description

Part of toy dataset for examples.

Usage

```
theta_mvnig
```

Format

List of parameters for input to `MVNIGmod` function

Examples

```
theta_mvvg
```

theta_mvvg *Toy Response Initial Parameter (MVVG)*

Description

Part of toy dataset for examples.

Usage

```
theta_mvvg
```

Format

List of parameters for input to `MVVGmod` function

Examples

```
theta_mvvg
```

X *Toy Covariate Matrices*

Description

Part of toy dataset for examples.

Usage

```
X
```

Format

List of covariate matrices for individual subjects

Examples

```
X
```

Y *Toy Response Matrices*

Description

Part of toy dataset for examples.

Usage

```
Y
```

Format

List of response matrices for individual subjects

Examples

```
Y
```

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