

Package ‘MVNGmod’

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Type Package

Title Matrix-Variate Non-Gaussian Linear Regression Models

Version 0.1.1

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Description An implementation of the expectation conditional maximization (ECM) algorithm for matrix-variate variance gamma (MVVG) and normal-inverse Gaussian (MVNIG) linear models. These models are designed for settings of multivariate analysis with clustered non-uniform observations and correlated responses. The package includes fitting and prediction functions for both models, and an example dataset from a periodontal on Gullah-speaking African Americans, with responses in 'gaad_res', and covariates in 'gaad_cov'. For more details on the matrix-variate distributions used, see Gal-
lauger & McNicholas (2019) <[doi:10.1016/j.spl.2018.08.012](https://doi.org/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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case_del	<i>Case Deletion for MVNG Models</i>
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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

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

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

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

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

Dipankar Bandyopadhyay

Qingyang Liu

Examples

```
mod <- MVNIGmod(Y,X,theta_mvniq)
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

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

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

where $A_i = \mathbf{1}_{n_i} \times \underline{a}^T$, $\Sigma_i = I_{n_i} + r(\mathbf{1}_{n_i} \mathbf{1}_{n_i}^T - I_{n_i})$, $\delta(X; M, \Sigma, \Psi) = \text{matlib} :: \text{tr}(\Sigma^{-1}(X - M)\Psi^{-1}(X - M)^T)$, $\rho(A, \Sigma, \Psi) = \text{matlib} :: \text{tr}(\Sigma^{-1}A\Psi^{-1}A^T)$, 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_mvni)
```

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

<code>Y</code>	List of $n_i \times p$ response matrices. Matrices must have same number of columns.
<code>X</code>	List of $n_i \times q$ design matrices. Matrices must have same number of columns.
<code>theta_g</code>	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.
<code>stopping</code>	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
<code>max_iter</code>	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

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

where $A_i = \mathbf{1}_{n_i} \times \underline{a}^T$, $\Sigma_i = I_{n_i} + r(\mathbf{1}_{n_i} \mathbf{1}_{n_i}^T - I_{n_i})$, $\delta(X; M, \Sigma, \Psi) = \text{matlib} :: \text{tr}(\Sigma^{-1}(X - M) \Psi^{-1} (X - M)^T)$, $\rho(A, \Sigma, \Psi) = \text{matlib} :: \text{tr}(\Sigma^{-1} A \Psi^{-1} A^T)$, 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	<i>Toy Response Initial Parameter (MVNIg)</i>
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Description

Part of toy dataset for examples.

Usage

theta_mvniG

Format

List of parameters for input to MVNIgmod function

Examples

theta_mvniG

theta_mvniG	<i>Toy Response Initial Parameter (MVNIg)</i>
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Description

Part of toy dataset for examples.

Usage

theta_mvniG

Format

List of parameters for input to MVNIgmod function

Examples

theta_mvniG

X	<i>Toy Covariate Matrices</i>
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Description

Part of toy dataset for examples.

Usage

X

Format

List of covariate matrices for individual subjects

Examples

X

Y	<i>Toy Response Matrices</i>
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Description

Part of toy dataset for examples.

Usage

Y

Format

List of response matrices for individual subjects

Examples

Y

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