

# Package ‘lglasso’

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**Type** Package

**Title** Longitudinal Graphical Lasso

**Version** 0.1.0

**Description** For high-dimensional correlated observations, this package carries out the  $L_1$  penalized maximum likelihood estimation of the precision matrix (network) and the correlation parameters. The correlated data can be longitudinal data (may be irregularly spaced) with dampening correlation or clustered data with uniform correlation. For the details of the algorithms, please see the paper Jie Zhou et al. Identifying Microbial Interaction Networks Based on Irregularly Spaced Longitudinal 16S rRNA sequence data <[doi:10.1101/2021.11.26.470159](https://doi.org/10.1101/2021.11.26.470159)>.

**License** GPL-3

**Encoding** UTF-8

**LazyData** true

**RoxygenNote** 7.1.2

**URL** <https://github.com/jiezhou-2/lglasso>

**Suggests** knitr, rmarkdown

**Imports** stats, glasso

**Depends** R (>= 2.10)

**NeedsCompilation** no

**Author** Jie Zhou [aut, cre, cph],  
Jiang Gui [aut],  
Weston Viles [aut],  
Anne Hoen [aut]

**Maintainer** Jie Zhou <[chowstat@gmail.com](mailto:chowstat@gmail.com)>

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heterlongraph	<i>Estimates of correlation parameters and precision matrix</i>
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### Description

Estimates of correlation parameters and precision matrix

### Usage

```
heterlongraph(data, rho, type, tole, lower, upper)
```

### Arguments

data	Data matrix in which the first column is subject id, the second column is the time points of observation. Columns 2 to (p+2) is the observations for p variables.
rho	Tuning parameter used in graphical lasso
type	Type of correlation function, which can take either "abs" or "sqr".
tole	Error tolerance for determination of convergence of EM algorithm
lower	Lower bound for prediction of correlation parameter tau
upper	Upper bound for prediction of correlation parameter tau

### Value

S list with three components which are the final estimate of alpha, tau and precision matrix omega

### Author(s)

Jie Zhou

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homolograph	<i>Estimate of precision matrix and autocorrelation parameter for homogeneous model</i>
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**Description**

Estimate of precision matrix and autocorrelation parameter for homogeneous model

**Usage**

```
homolograph(data, rho, type, tole, lower, upper)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is the time points of observation. Columns 2 to (p+2) is the observations for p variables.
rho	Tuning parameter for graphical lasso
type	Type of correlation function, which can take either "abs" or "qua".
tole	Error tolerance for determination of convergence of EM algorithm
lower	Lower bound for prediction of correlation parameter tau
upper	Upper bound for prediction of correlation parameter tau

**Value**

A list for estimates of precision matrix and correlation parameter for given tuning parameter

**Author(s)**

Jie Zhou

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iss	<i>Quasi covariance matrix for subject i</i>
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**Description**

Quasi covariance matrix for subject i

**Usage**

```
iss(idata, itau, type)
```

**Arguments**

idata	Data matrix for the subject $i$ in which the first column is subject (cluster) id, the second column stands for the time points () of observation. Columns 2 to $(p+2)$ is the observations for $p$ variables respectively.
itau	Correlation parameter
type	Type of correlation function, which typically take either 0, 1 or 2.

**Value**

Empirical quasi covariance matrix

**Author(s)**

Jie Zhou

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lglasso

*Graphical Lasso for Longitudinal Data*


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**Description**

This function implements the  $L_1$  penalized maximum likelihood estimation for precision matrix (network) based on correlated data, e.g., irregularly spaced longitudinal data. It can be regarded as an extension of the package glasso (Friedman, Hastie and Tibshirani, 2008) which aims to find the sparse estimate of the network from independent continuous data.

**Usage**

```
lglasso(
  data,
  rho,
  heter = TRUE,
  type = 1,
  tole = 0.01,
  lower = 0.01,
  upper = 10
)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is time points of observations for temporal data or site id for spatial data. Columns 3 to $(p+2)$ is the observations for $p$ variables.
rho	Tuning parameter used in $L_1$ penalty

heter	Binary variable TRUE or FALSE, indicating heterogeneous model or homogeneous model is fitted. In heterogeneous model, subjects are allowed to have his/her own temporal correlation parameter $\tau_i$ ; while in homogeneous model, all the subjects are assumed to share the same temporal correlation parameter, i.e., $\tau_1 = \tau_2 = \dots = \tau_m$ .
type	A positive number which specifies the correlation function. The general form of correlation function is given by $\exp(\tau  t_i - t_j ^{\text{type}})$ . In which $\text{type} = 0$ can be used for spatial correlation while $\text{type} > 0$ are used for temporal correlation. For latter, the default value is set to be $\text{type} = 1$ .
tole	Threshold for convergence. Default value is $1e-2$ . Iterations stop when maximum absolute difference between consecutive estimates of parameter change is less than <i>tole</i> .
lower	Lower bound for predicts of correlation parameter $\tau$ . Default value is $1e-2$ . The estimate of $\tau(\alpha)$ will be searched in the interval $[\text{lower}, \text{upper}]$ , where parameter <i>upper</i> is explained in the following.
upper	Upper bound for predicts of correlation parameter $\tau$ .

### Value

If *heter*=TRUE, then a list with three components is returned which are respectively the estimate of parameter  $\alpha$  in exponent distribution, correlation parameter  $\tau$  and precision matrix  $\omega$ . If *heter*=FALSE, then a list with two components is returned which are respectively the estimate of correlation parameter  $\tau$  and precision matrix  $\omega$ .

### Author(s)

Jie Zhou

### References

Jie Zhou, Jiang Gui, Weston D.Viles, Anne G.Hoen Identifying Microbial Interaction Networks Based on Irregularly Spaced Longitudinal 16S rRNA sequence data. bioRxiv 2021.11.26.470159; doi: <https://doi.org/10.1101/2021.11.26.470159>

Friedman J, Tibshirani TH and R. Glasso: Graphical Lasso: Estimation of Gaussian Graphical Models.; 2019. Accessed November 28, 2021. <https://CRAN.R-project.org/package=glasso>

Friedman J, Hastie T, Tibshirani TH, Sparse inverse covariance estimation with the graphical lasso, Biostatistics, Volume 9, Issue 3, July 2008, Pages 432–441, <https://doi.org/10.1093/biostatistics/kxm045>

### Examples

```
sample_data[1:5,1:5]
dim(sample_data)
## Heterogeneous model with dampening correlation rate using the first three clusters
a=lglasso(data = sample_data[1:11,], rho = 0.7, heter=TRUE, type=1)
### Estimates of correlation parameters
a$tau
### Sub-network for the first five variables
a$omega[1:5,1:5]
```

```

### Total number of the edges in the estimated network
(length(which(a$omega!=0))-ncol(a$omega))/2
## Homogeneous model with dampening correlation rate using the first three clusters
b=lglasso(data = sample_data[1:11,], rho = 0.7,heter=FALSE,type=1)
### Estimates of correlation parameters
b$tau
### Sub-network for the first five variables
b$omega[1:5,1:5]
### Total number of the edges in the estimated network
(length(which(b$omega!=0))-ncol(b$omega))/2
## Heterogeneous model with uniform correlation rate using the first three clusters
c=lglasso(data = sample_data[1:11,], rho = 0.7,heter=TRUE,type=0)
### Estimates of correlation parameters
c$tau
### Sub-network for the first five variables
c$omega[1:5,1:5]
### Total number of the edges in the estimated network
(length(which(c$omega!=0))-ncol(c$omega))/2
## Homogeneous model with uniform correlation rate using the first three clusters
d=lglasso(data = sample_data[1:11,], rho = 0.7,heter=FALSE,type=0)
### Estimates of correlation parameters
d$tau
### Sub-network for the first five variables
d$omega[1:5,1:5]
### Total number of the edges in the estimated network
(length(which(d$omega!=0))-ncol(d$omega))/2

```

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lli\_homo

*full log likelihood used in EBIC computation*


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## Description

full log likelihood used in EBIC computation

## Usage

```
lli_homo(idata, omega, tau, type)
```

## Arguments

idata	Data matrix for the subject $i$ in which the first column is id for subject, the second column is the time points of observation. Columns 2 to $(p+2)$ is the observations for $p$ variables.
omega	Precision matrix
tau	Correlation parameter
type	Type of correlation function, which can take either "abs" or "qua".

**Value**

Value of likelihood function for subject  $i$  at given  $\omega$  and  $\tau$

**Author(s)**

Jie Zhou

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ll_homo	<i>Value of likelihood function at given parameter</i>
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**Description**

Value of likelihood function at given parameter

**Usage**

```
ll_homo(data, omega, tau, type)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is the time points of observation. Columns 2 to $(p+2)$ is the observations for $p$ variables.
omega	Precision matrix
tau	Correlation parameter
type	Type of correlation function, which can take either "abs" or "qua".

**Value**

Value of likelihood function at given  $\omega$  and  $\tau$

**Author(s)**

Jie Zhou

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logdensity	<i>Complete likelihood function used in EM algorithm of heterogeneous marginal graphical lasso model</i>
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**Description**

Complete likelihood function used in EM algorithm of heterogeneous marginal graphical lasso model

**Usage**

```
logdensity(idata, omega, tau, alpha, type)
```

**Arguments**

idata	Data matrix for the subject $i$ in which the first column is id for subject, the second column is the time points of observation. Columns 2 to $(p+2)$ is the observations for $p$ variables.
omega	Precision matrix
tau	Correlation parameter
alpha	Parameter in exponential distribution
type	Type of correlation function, which can take either "abs" or "qua".

**Value**

Value of complete likelihood function at given value of omega, tau and alpha

**Author(s)**

Jie Zhou

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mle	<i>Maximum Likelihood Estimate of Precision Matrix and Correlation Parameters for Given Network</i>
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**Description**

Maximum Likelihood Estimate of Precision Matrix and Correlation Parameters for Given Network

**Usage**

```
mle(
  data,
  network,
  heter = TRUE,
  type = 1,
  tole = 0.01,
  lower = 0.01,
  upper = 10
)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is time points of observations for temporal data or site id for spatial data. Columns 3 to (p+2) is the observations for p variables.
network	The network selected by function <code>lglasso</code>
heter	Binary variable TRUE or FALSE, indicating heterogeneous model or homogeneous model is fitted. In heterogeneous model, subjects are allowed to have his/her own temporal correlation parameter $\tau_i$ ; while in homogeneous model, all the subjects are assumed to share the same temporal correlation parameter, i.e., $\tau_1 = \tau_2 = \dots = \tau_m$ .
type	A positive number which specify the correlation function. The general form of correlation function is given by $\exp(\tau  t_i - t_j ^{type})$ . in which $type=0$ can be used for spatial correlation while $type>0$ are used for temporal correlation. For latter, the default value is set to be $type=1$ .
tole	Threshold for convergence. Default value is $1e-2$ . Iterations stop when maximum absolute difference between consecutive estimates of parameter change is less than <code>tole</code> .
lower	Lower bound for predicts of correlation parameter $\tau$ . Default value is $1e-2$ . The estimate of $\tau(\alpha)$ will be searched in the interval <code>[lower, upper]</code> , where parameter <code>upper</code> is explained in the following.
upper	Upper bound for predicts of correlation parameter $\tau$ .

**Value**

A list which include the maximum likelihood estimate of precision matrix, correlation parameter  $\tau$ . If `heter=TRUE`, the output also include the estimate of  $\alpha$  where  $\tau = \exp(\alpha)$

**Author(s)**

Jie Zhou

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mle_alpha	<i>Maximum likelihood estimate of correlation parameter for given structure of precision matrix</i>
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**Description**

Maximum likelihood estimate of correlation parameter for given structure of precision matrix

**Usage**

```
mle_alpha(data, alpha0, omega, type, tole, lower, upper)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is the time points of observation. Columns 2 to (p+2) is the observations for p variables.
alpha0	Initial value for the parameter in exponential distribution
omega	Fixed value for precision matrix
type	Type of correlation function, which can take either "abs" or "qua".
tole	Error tolerance for determination of convergence of EM algorithm
lower	Lower bound for prediction of correlation parameter tau
upper	Upper bound for prediction of correlation parameter tau

**Author(s)**

Jie Zhou

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mle_net	<i>Title</i>
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**Description**

Title

**Usage**

```
mle_net(data, priori)
```

**Arguments**

data	A Longitudinal data set
priori	Given structure of precision matrix

**Value**

The maximum likelihood estimation

**Author(s)**

Jie Zhou

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mle_tau	<i>Estiamte of precision matrix and autocorrelaton parameter for homogeneous model</i>
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**Description**

Estiamte of precision matrix and autocorrelaton parameter for homogeneous model

**Usage**

```
mle_tau(data, omega, type, lower, upper)
```

**Arguments**

data	Data matrix in which the first column is subject id, the second column is the time points of observation. Columns 2 to (p+2) is the observations for p variables.
omega	The maximum likelihood estiamte of precision matrix
type	Type of correlation function, which can take either "abs" or "qua".
lower	Lower bound for prediction of correlation parameter tau
upper	Upper bound for prediction of correlation parameter tau

**Value**

A list for estimates of precision matrix and correlation parameter for given tuning parameter

**Author(s)**

Jie Zhou

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phifunction	<i>Construct the temporal component fo correlation function</i>
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**Description**

Construct the temporal component fo correlation function

**Usage**

```
phifunction(t, tau, type = 1)
```

**Arguments**

t	Time points of observations
tau	correlation parameter
type	The type of correlation function, which typically take either 0,1 or 2.

**Value**

A square matrix with dimension equal to the length of vector t

**Author(s)**

Jie Zhou

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sample_data	<i>Sample Data</i>
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**Description**

The sample data are subset of a larger longitudinal data set from an ongoing large-scale prospective project. There are 13 cluster are involved in the sample data.

**Usage**

```
sample_data
```

**Format**

A 100-by-22 matrix

**Column 1** Cluster id;

**Column 2** Time points of observations;

**Columns 3-22** Observations for 20 microbes.

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