Package ‘fnets’

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Type Package

Title Factor-Adjusted Network Estimation and Forecasting for High-Dimensional Time Series

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Description
Implements methods for network estimation and forecasting of high-dimensional time series exhibiting strong serial and cross-sectional correlations under a factor-adjusted vector autoregressive model.
See Barigozzi, Cho and Owens (2022) <arXiv:2201.06110> for further descriptions of FNETS methodology and
Owens, Cho and Barigozzi (2023) <arXiv:2301.11675> accompanying the R package.

Depends R (>= 4.1.0)

Imports lpSolve,
parallel,
doParallel,
foreach,
MASS,
fields,
igraph,
RColorBrewer

License GPL (>= 3)

Encoding UTF-8

LazyData false

RoxygenNote 7.1.2

Suggests testthat (>= 3.0.0)

Config/testthat/edition 3

R topics documented:

`factor.number` *Factor number selection methods*

Description

Methods to estimate the number of factor. When `method = 'er'`, the factor number is estimated by maximising the ration of successive eigenvalues. When `method = 'ic'`, the information criterion-methods discussed in Hallin and Liška (2007) (when `fm.restricted = FALSE`) and Alessi, Barigozzi and Capasso (2010) (when `fm.restricted = TRUE`) are implemented. The information criterion called by `ic.op = 5` (as an argument to `fnets` or `fnets.factor.model`) is recommended by default.

Usage

```
factor.number(
  x,
  fm.restricted = FALSE,
  method = c("ic", "er"),
  q.max = NULL,
  center = TRUE
)
```

Arguments

`x`	input time series matrix, with each row representing a variable and each column containing the observations at a given time
`fm.restricted`	whether to estimate the number of restricted or unrestricted factors
`method`	A string specifying the factor number selection method; possible values are:

- "ic" information criteria-based methods of Alessi, Barigozzi & Capasso (2010) when `fm.restricted = TRUE` or Hallin and Liška (2007) when `fm.restricted = FALSE`
- "er" eigenvalue ratio of Ahn and Horenstein (2013) when `fm.restricted = TRUE` or Avarucci et al. (2022) when `fm.restricted = FALSE`

`q.max` maximum number of factors; if `q.max = NULL`, a default value is selected as `min(50, floor(sqrt(min(dim(x)[2] - 1, dim(x)[1]))))`

`center` whether to de-mean the input `x` row-wise

Details

For further details, see references.

Value

S3 object of class `factor.number`. If `method = "ic"`, a vector containing minimisers of the six information criteria, otherwise, the maximiser of the eigenvalue ratio

References

Ahn, S. C. & Horenstein, A. R. (2013) Eigenvalue ratio test for the number of factors. Econometrica, 81(3), 1203–1227.

Alessi, L., Barigozzi, M., and Capasso, M. (2010) Improved penalization for determining the number of factors in approximate factor models. Statistics & Probability Letters, 80(23-24):1806–1813.

Avarucci, M., Cavicchioli, M., Forni, M., & Zaffaroni, P. (2022) The main business cycle shock(s): Frequency-band estimation of the number of dynamic factors.

Hallin, M. & Liška, R. (2007) Determining the number of factors in the general dynamic factor model. Journal of the American Statistical Association, 102(478), 603–617.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

See Also

plot.factor.number, print.factor.number

Examples

```
library(fnets)

## Alessi, Barigozzi, and Capasso method for restricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

abc <- factor.number(x, fm.restricted = TRUE)
```

```
print(abc)
plot(abc)

## Eigenvalue ratio method
er <- factor.number(x, method = "er", fm.restricted = TRUE)
print(er)
plot(er)

## Hallin and Liška method for unrestricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

hl <- factor.number(x, fm.restricted = FALSE)
print(hl)
plot(hl)
```

---

fnets *Factor-adjusted network estimation*

Description

Under a factor-adjusted vector autoregressive (VAR) model, the function estimates the spectral density and autocovariance matrices of the factor-driven common component and the idiosyncratic VAR process, the impulse response functions and common shocks for the common component, and VAR parameters, innovation covariance matrix and long-run partial correlations for the idiosyncratic component.

Usage

```
fnets(
  x,
  center = TRUE,
  fm.restricted = FALSE,
  q = c("ic", "er"),
  ic.op = NULL,
  kern.bw = NULL,
  common.args = list(factor.var.order = NULL, max.var.order = NULL, trunc.lags = 20,
    n.perm = 10),
  var.order = 1,
  var.method = c("lasso", "ds"),
  var.args = list(n.iter = NULL, n.cores = 1),
  do.threshold = FALSE,
  do.lrpc = TRUE,
  lrpc.adaptive = FALSE,
```

```
  tuning.args = list(tuning = c("cv", "bic"), n.folds = 1, penalty = NULL, path.length
    = 10)
)
```

Arguments

- `x` — input time series matrix, with each row representing a variable and each column containing the observations at a given time
- `center` — whether to de-mean the input `x` row-wise
- `fm.restricted` — whether to estimate a restricted factor model using static PCA
- `q` — Either the number of factors or a string specifying the factor number selection method; possible values are:
  - `"ic"` information criteria-based methods of Alessi, Barigozzi & Capasso (2010) when `fm.restricted = TRUE` or Hallin and Liška (2007) when `fm.restricted = FALSE`
  - `"er"` eigenvalue ratio of Ahn and Horenstein (2013) when `fm.restricted = TRUE` or Avarucci et al. (2022) when `fm.restricted = FALSE`

  see factor.number.
- `ic.op` — choice of the information criterion penalty, see factor.number for further details
- `kern.bw` — a positive integer specifying the kernel bandwidth for dynamic PCA; by default, it is set to `floor(4 *(dim(x)[2]/log(dim(x)[2]))^(1/3)))`. When `fm.restricted = TRUE`, it is used to compute the number of lags for which autocovariance matrices are estimated
- `common.args` — a list specifying the tuning parameters required for estimating the impulse response functions and common shocks. It contains:
  - `factor.var.order` order of the blockwise VAR representation of the common component. If `factor.var.order = NULL`, it is selected blockwise by Schwarz criterion
  - `max.var.order` maximum blockwise VAR order for the Schwarz criterion
  - `trunc.lags` truncation lag for impulse response function estimation
  - `n.perm` number of cross-sectional permutations involved in impulse response function estimation
- `var.order` — order of the idiosyncratic VAR process; if a vector of integers is supplied, the order is chosen via `tuning`
- `var.method` — a string specifying the method to be adopted for idiosyncratic VAR process estimation; possible values are:
  - `"lasso"` Lasso-type `l1`-regularised `M`-estimation
  - `"ds"` Dantzig Selector-type constrained `l1`-minimisation
- `var.args` — a list specifying the tuning parameters required for estimating the idiosyncratic VAR process. It contains:
  - `n.iter` maximum number of descent steps, by default depends on `var.order`; applicable when `var.method = "lasso"`
  - `n.cores` number of cores to use for parallel computing, see makePSOCKcluster; applicable when `var.method = "ds"`

`do.threshold` whether to perform adaptive thresholding of all parameter estimators with threshold

`do.lrpc` whether to estimate the long-run partial correlation

`lrpc.adaptive` whether to use the adaptive estimation procedure

`tuning.args` a list specifying arguments for `tuning` for selecting the tuning parameters involved in VAR parameter and (long-run) partial correlation matrix estimation. It contains:

- `tuning` a string specifying the selection procedure for `var.order` and `lambda`; possible values are:
  - `"cv"` cross validation
  - `"bic"` information criterion
- `n.folds` if `tuning = "cv"`, positive integer number of folds
- `penalty` if `tuning = "bic"`, penalty multiplier between 0 and 1; if `penalty = NULL`, it is set to `1/(1+exp(dim(x)[1])/dim(x)[2]))` by default
- `path.length` positive integer number of regularisation parameter values to consider; a sequence is generated automatically based in this value

Details

See Barigozzi, Cho and Owens (2022) and Owens, Cho and Barigozzi (2022) for further details. List arguments do not need to be specified with all list components; any missing entries will be filled in with the default argument.

Value

an S3 object of class `fnets`, which contains the following fields:

`q` number of factors

`spec` if `fm.restricted = FALSE` a list containing estimates of the spectral density matrices for `x`, common and idiosyncratic components

`acv` a list containing estimates of the autocovariance matrices for `x`, common and idiosyncratic components

`loadings` if `fm.restricted = TRUE`, factor loadings; if `fm.restricted = FALSE` and `q >= 1`, a list containing estimators of the impulse response functions (as an array of dimension `(p, q, trunc.lags + 2)`)

`factors` if `fm.restricted = TRUE`, factor series; else, common shocks (an array of dimension `(q, n)`)

`idio.var` a list containing the following fields:

- `beta` estimate of VAR parameter matrix; each column contains parameter estimates for the regression model for a given variable
- `Gamma` estimate of the innovation covariance matrix
- `lambda` regularisation parameter
- `var.order` VAR order

`lrpc` see the output of par.lrpc

`mean.x`	if `center = TRUE`, returns a vector containing row-wise sample means of `x`; if `center = FALSE`, returns a vector of zeros
`var.method`	input parameter
`do.lrpc`	input parameter
`kern.bw`	input parameter

References

Ahn, S. C. & Horenstein, A. R. (2013) Eigenvalue ratio test for the number of factors. Econometrica, 81(3), 1203–1227.

Alessi, L., Barigozzi, M., & Capasso, M. (2010) Improved penalization for determining the number of factors in approximate factor models. Statistics & Probability Letters, 80(23-24):1806–1813.

Avarucci, M., Cavicchioli, M., Forni, M., & Zaffaroni, P. (2022) The main business cycle shock(s): Frequency-band estimation of the number of dynamic factors.

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Hallin, M. & Liška, R. (2007) Determining the number of factors in the general dynamic factor model. Journal of the American Statistical Association, 102(478), 603–617.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

See Also

predict.fnets, plot.fnets, print.fnets

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
  do.threshold = TRUE,
  var.args = list(n.cores = 2)
)
pre <- predict(out, common.method = "unrestricted")
plot(out, type = "granger", display = "network")
plot(out, type = "lrpc", display = "heatmap")
```

fnets.factor.model *Factor model estimation*

Description

Performs factor modelling under either restricted (static) or unrestricted (dynamic) factor models

Usage

```
fnets.factor.model(
  x,
  center = TRUE,
  fm.restricted = FALSE,
  q = c("ic", "er"),
  ic.op = NULL,
  kern.bw = NULL,
 common.args = list(factor.var.order = NULL, max.var.order = NULL, trunc.lags = 20,
    n.perm = 10)
)
```

Arguments

x	input time series matrix, with each row representing a variable and each column containing the observations at a given time
center	whether to de-mean the input x row-wise
fm.restricted	whether to estimate a restricted factor model using static PCA
q	Either a string specifying the factor number selection method when fm.restricted = TRUE; possible values are: • "ic" information criteria-based methods of Alessi, Barigozzi & Capasso (2010) when fm.restricted = TRUE or Hallin and Liška (2007) when fm.restricted = FALSE • "er" eigenvalue ratio of Ahn and Horenstein (2013) when fm.restricted = TRUE or Avarucci et al. (2022) when fm.restricted = FALSE or the number of unrestricted factors, see factor.number
ic.op	choice of the information criterion penalty, see hl.factor.number or abc.factor.number for further details
kern.bw	a positive integer specifying the kernel bandwidth for dynamic PCA; by default, it is set to floor(4 *(dim(x)[2]/log(dim(x)[2]))^(1/3))). When fm.restricted = TRUE, it is used to compute the number of lags for which autocovariance matrices are estimated
common.args	a list specifying the tuning parameters required for estimating the impulse response functions and common shocks. It contains: • factor.var.order order of the blockwise VAR representation of the common component. If factor.var.order = NULL, it is selected blockwise by Schwarz criterion

- `max.var.order` maximum blockwise VAR order for the Schwarz criterion
- `trunc.lags` truncation lag for impulse response function estimation
- `n.perm` number of cross-sectional permutations involved in impulse response function estimation

Details

See Barigozzi, Cho and Owens (2022) for further details.

Value

an S3 object of class `fm`, which contains the following fields:

`q`	number of factors
`spec`	if `fm.restricted = FALSE` a list containing estimates of the spectral density matrices for `x`, common and idiosyncratic components
`acv`	a list containing estimates of the autocovariance matrices for `x`, common and idiosyncratic components
`loadings`	if `fm.restricted = TRUE`, factor loadings; if `fm.restricted = FALSE` and `q >= 1`, a list containing estimators of the impulse response functions (as an array of dimension `(p, q, trunc.lags + 2)`)
`factors`	if `fm.restricted = TRUE`, factor series; else, common shocks (an array of dimension `(q, n)`)
`mean.x`	if `center = TRUE`, returns a vector containing row-wise sample means of `x`; if `center = FALSE`, returns a vector of zeros

References

Ahn, S. C. & Horenstein, A. R. (2013) Eigenvalue ratio test for the number of factors. Econometrica, 81(3), 1203–1227.

Alessi, L., Barigozzi, M., & Capasso, M. (2010) Improved penalization for determining the number of factors in approximate factor models. Statistics & Probability Letters, 80(23-24):1806–1813.

Avarucci, M., Cavicchioli, M., Forni, M., & Zaffaroni, P. (2022) The main business cycle shock(s): Frequency-band estimation of the number of dynamic factors.

Barigozzi, M., Cho, H. & Owens, D. (2022) Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Hallin, M. & Liška, R. (2007) Determining the number of factors in the general dynamic factor model. Journal of the American Statistical Association, 102(478), 603–617.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

See Also

print.fm, predict.fm

Examples

```
set.seed(1234)
n <- 500
p <- 50
common <- sim.restricted(n, p)
x <- common$data + matrix(rnorm(n * p), nrow = p)
out <- fnets.factor.model(x, fm.restricted = FALSE)
```

---

fnets.var *l1-regularised Yule-Walker estimation for VAR processes*

Description

Estimates the VAR parameter matrices via l1-regularised Yule-Walker estimation and innovation covariance matrix via constrained l1-minimisation.

Usage

```
fnets.var(
  x,
  center = TRUE,
  method = c("lasso", "ds"),
  lambda = NULL,
  var.order = 1,
 tuning.args = list(tuning = c("cv", "bic"), n.folds = 1, penalty = NULL, path.length
    = 10),
  do.threshold = FALSE,
  n.iter = NULL,
  tol = 0,
  n.cores = 1
)
```

Arguments

x	input time series matrix, with each row representing a variable and each column containing the observations at a given time
center	whether to de-mean the input x row-wise
method	a string specifying the method to be adopted for VAR process estimation; possible values are: • "lasso" Lasso-type l1-regularised M-estimation • "ds" Dantzig Selector-type constrained l1-minimisation
lambda	l1-regularisation parameter; if lambda = NULL, tuning is employed to select the parameter

var.order	order of the VAR process; if a vector of integers is supplied, the order is chosen via tuning
tuning.args	a list specifying arguments for tuning for selecting the regularisation parameter (and VAR order). It contains: • tuning a string specifying the selection procedure for var.order and lambda; possible values are: – "cv" cross validation – "bic" information criterion • n.folds if tuning = "cv", positive integer number of folds • penalty if tuning = "bic", penalty multiplier between 0 and 1; if penalty = NULL, it is set to 1/(1+exp(dim(x)[1])/dim(x)[2])) by default • path.length positive integer number of regularisation parameter values to consider; a sequence is generated automatically based in this value
do.threshold	whether to perform adaptive thresholding of VAR parameter estimator with threshold
n.iter	maximum number of descent steps, by default depends on var.order; applicable when method = "lasso"
tol	numerical tolerance for increases in the loss function; applicable when method = "lasso"
n.cores	number of cores to use for parallel computing, see makePSOCKcluster; applicable when method = "ds"

Details

Further information can be found in Barigozzi, Cho and Owens (2022).

Value

a list which contains the following fields:

beta	estimate of VAR parameter matrix; each column contains parameter estimates for the regression model for a given variable
Gamma	estimate of the innovation covariance matrix
lambda	l1-regularisation parameter
var.order	VAR order
mean.x	if center = TRUE, returns a vector containing row-wise sample means of x; if center = FALSE, returns a vector of zeros

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

Examples

```
library(fnets)

set.seed(123)
n <- 500
p <- 50
idio <- sim.var(n, p)
x <- idio$data

fv <- fnets.var(x,
  n.cores = 2
)
```

`network` *Convert networks into igraph objects*

Description

Convert networks into igraph objects

Usage

```
network(object, ...)
```

Arguments

`object`	object
`...`	additional arguments

See Also

network.fnets

`network.fnets` *Convert networks estimated by fnets into igraph objects*

Description

Converts S3 objects of class `fnets` into a network. Produces an igraph object for the three networks underlying factor-adjusted VAR processes: (i) directed network representing Granger causal linkages, as given by estimated VAR transition matrices summed across the lags, (ii) undirected network representing contemporaneous linkages after accounting for lead-lag dependence, as given by partial correlations of VAR innovations, (iii) undirected network summarising (i) and (ii) as given by long-run partial correlations of VAR processes. When plotting the network, note that the edge weights may be negative since they correspond to the entries of the estimators of VAR parameters and (long-run) partial correlations.

Usage

```
## S3 method for class 'fnets'
network(
  object,
  type = c("granger", "pc", "lrpc"),
  names = NA,
  groups = NA,
  group.colours = NA,
  ...
)
```

Arguments

`object`	`fnets` object
`type`	a string specifying which of the above three networks (i)–(iii) to visualise; possible values are • `"granger"` directed network representing Granger causal linkages • `"pc"` undirected network representing contemporaneous linkages; available when `object$do.lrpc = TRUE` • `"lrpc"` undirected network summarising Granger causal and contemporaneous linkages; available when `x$do.lrpc = TRUE`
`names`	a character vector containing the names of the vertices
`groups`	an integer vector denoting any group structure of the vertices
`group.colours`	a vector denoting colours corresponding to `groups`
`...`	additional arguments to `igraph::graph_from_adjacency_matrix`

Details

See Barigozzi, Cho and Owens (2022) for further details.

Value

a list containing

`network`	`igraph` object
`names`	input argument
`groups`	input argument
`grp.col`	vector of colours corresponding to each node
`...`	additional arguments to `igraph::graph_from_adjacency_matrix`

See Also

fnets, plot.fnets

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
  do.threshold = TRUE,
  var.args = list(n.cores = 2)
)
net <- network(out, type = "granger")$network
plot(net, layout = igraph::layout_in_circle(net))
network(out, type = "pc")
network(out, type = "lrpc")
```

`par.lrpc` *Parametric estimation of long-run partial correlations of factor-adjusted VAR processes*

Description

Returns a parametric estimate of long-run partial correlations of the VAR process from the VAR parameter estimates and the inverse of innovation covariance matrix obtained via constrained `l1`-minimisation.

Usage

```
par.lrpc(
  object,
  eta = NULL,
  tuning.args = list(n.folds = 1, path.length = 10),
  lrpc.adaptive = FALSE,
  eta.adaptive = NULL,
  do.correct = TRUE,
  do.threshold = FALSE,
  n.cores = 1
)
```

Arguments

`object`	`fnets` object
`eta`	`l1`-regularisation parameter; if `eta = NULL`, it is selected by cross validation
`tuning.args`	a list specifying arguments for the cross validation procedure for selecting the tuning parameter involved in long-run partial correlation matrix estimation. It contains:

- `n.folds` positive integer number of folds
- `path.length` positive integer number of regularisation parameter values to consider; a sequence is generated automatically based in this value

`lrpc.adaptive`	whether to use the adaptive estimation procedure
`eta.adaptive`	`l1`-regularisation parameter for Step 1 of the adaptive estimation procedure; if `eta.adaptive = NULL`, the default choice is `2 * sqrt(log(dim(x)[1])/dim(x)[2])`
`do.correct`	whether to correct for any negative entries in the diagonals of the inverse of long-run covariance matrix
`do.threshold`	whether to perform adaptive thresholding of `Delta` and `Omega` parameter estimators with threshold
`n.cores`	number of cores to use for parallel computing, see makePSOCKcluster

Details

See Barigozzi, Cho and Owens (2022) for further details, and Cai, Liu and Zhou (2016) for further details on the adaptive estimation procedure.

Value

a list containing

`Delta`	estimated inverse of the innovation covariance matrix
`Omega`	estimated inverse of the long-run covariance matrix
`pc`	estimated innovation partial correlation matrix
`lrpc`	estimated long-run partial correlation matrix
`eta`	`l1`-regularisation parameter
`lrpc.adaptive`	input argument

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Cai, T. T., Liu, W., & Zhou, H. H. (2016) Estimating sparse precision matrix: Optimal rates of convergence and adaptive estimation. The Annals of Statistics, 44(2), 455-488.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
```

```
out <- fnets(x, do.lrpc = FALSE, var.args = list(n.cores = 2))
plrpc <- par.lrpc(out, n.cores = 2)
out$lrpc <- plrpc
out$do.lrpc <- TRUE
plot(out, type = "pc", display = "network")
plot(out, type = "lrpc", display = "heatmap")
```

`plot.factor.number` *Plot factor number*

Description

Plots the eigenvalue ratio or information criteria from a `factor.number` object

Usage

```
## S3 method for class 'factor.number'
plot(x, ...)
```

Arguments

`x`	`factor.number` object
`...`	not used

Value

NULL, printed to console

See Also

factor.number

Examples

```
library(fnets)

## Alessi, Barigozzi, and Capasso method for restricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

abc <- factor.number(x, fm.restricted = TRUE)
print(abc)
plot(abc)
```

```
## Eigenvalue ratio method
er <- factor.number(x, method = "er", fm.restricted = TRUE)
print(er)
plot(er)

## Hallin and Liška method for unrestricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

hl <- factor.number(x, fm.restricted = FALSE)
print(hl)
plot(hl)
```

---

plot.fnets *Plotting the networks estimated by fnets*

Description

Plotting method for S3 objects of class `fnets`. When `display = "network"` or "heatmap", it produces a plot visualising three networks underlying factor-adjusted VAR processes: (i) directed network representing Granger causal linkages, as given by estimated VAR transition matrices summed across the lags, (ii) undirected network representing contemporaneous linkages after accounting for lead-lag dependence, as given by partial correlations of VAR innovations, (iii) undirected network summarising (i) and (ii) as given by long-run partial correlations of VAR processes. Edge widths are determined by edge weights. When `display = "tuning"`, it produces up to two plots (when `do.larpc = TRUE`) visualising the outcome of CV or IC adopted for selecting the `l1`-regularisation parameters and the VAR order.

Usage

```
## S3 method for class 'fnets'
plot(
  x,
  type = c("granger", "pc", "lrpc"),
  display = c("network", "heatmap", "tuning"),
  names = NA,
  groups = NA,
  group.colours = NA,
  ...
)
```

Arguments

x	`fnets` object

`type` a string specifying which of the above three networks (i)–(iii) to visualise when `display = "network"` or `display = "heatmap"`; possible values are
- `"granger"` directed network representing Granger causal linkages
- `"pc"` undirected network representing contemporaneous linkages; available when `x$do.lrpc = TRUE`
- `"lrpc"` undirected network summarising Granger causal and contemporaneous linkages; available when `x$do.lrpc = TRUE`

`display` a string specifying which plot to produce; possible values are
- `"network"` visualise the network as an `igraph` object, see plot.igraph
- `"heatmap"` visualise the network as a heatmap, see imagePlot
- `"tuning"` visualise the outcome from CV or IC (specified by `tuning.args$tuning` of fnets) for selecting `l1`-regularisation parameters and the VAR order

`names` a character vector containing the names of the network vertices

`groups` an integer vector denoting any group structure of the network vertices

`group.colours` a vector denoting colours corresponding to `groups`

`...` additional arguments

Details

See Barigozzi, Cho and Owens (2022) for further details.

Value

A plot produced as per the input arguments

See Also

fnets

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
  do.threshold = TRUE,
  var.args = list(n.cores = 2)
)
plot(out, type = "granger", display = "network",
groups = rep(c(1,2), p/2), group.colours = c("orange","blue"))
plot(out, type = "lrpc", display = "heatmap")
plot(out, display = "tuning")
```

plot.threshold *Plotting the thresholding procedure*

Description

Plotting method for S3 objects of class `threshold`. Produces a plot visualising three diagnostics for the thresholding procedure, with threshold values t_k (x axis) against (i) Ratio_k, the ratio of the number of non-zero to zero entries in the matrix, as the threshold varies (ii) Diff_k, the first difference of `Ratio_k` (iii) |CUSUM_k|, the absolute scaled cumulative sums of `Diff_k`

Usage

```
## S3 method for class 'threshold'
plot(x, plots = c(TRUE, FALSE, TRUE), ...)
```

Arguments

`x`	`threshold` object
`plots`	logical vector, which plots to use (Ratio, Diff, CUSUM respectively)
`...`	additional arguments

Details

See Owens, Cho and Barigozzi (2022) for further details.

Value

A network plot produced as per the input arguments

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

See Also

threshold

Examples

```
## Not run:
library(fnets)

set.seed(123)
n <- 500
p <- 20
```

```
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
   var.args = list(n.cores = 2)
)
# Granger-causal network
th1 <- threshold(out$idio.var$beta)
plot(th1)
print(th1)
# Partial correlations
th2 <- threshold(out$lrpc$pc)
# Long-run partial correlations
th3 <- threshold(out$lrpc$lrpc)

## End(Not run)
```

---

predict.fm *Forecasting for factor models*

Description

Produces forecasts of the data input to `object` for a given forecasting horizon by estimating the best linear predictors of the common component

Usage

```
## S3 method for class 'fm'
predict(object, n.ahead = 1, fc.restricted = TRUE, r = c("ic", "er"), ...)
```

Arguments

`object`	`fm` object
`n.ahead`	forecasting horizon
`fc.restricted`	if `fc.restricted = TRUE`, the forecast is generated under a restricted factor model
`r`	number of static factors, or a string specifying the factor number selection method when `fc.restricted = TRUE`; possible values are: • `"ic"` information criteria of Alessi, Barigozzi & Capasso (2010) • `"er"` eigenvalue ratio of Ahn & Horenstein (2013)
`...`	not used

Value

a list containing

`is`	in-sample predictions
`forecast`	forecasts for the given forecasting horizon
`r`	factor number

See Also

fnets.factor.model

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
x <- common$data + rnorm(n*p)
out <- fnets.factor.model(x, fm.restricted = TRUE)
pre <- predict(out)
```

`predict.fnets` *Forecasting by fnets*

Description

Produces forecasts of the data for a given forecasting horizon by separately estimating the best linear predictors of common and idiosyncratic components

Usage

```
## S3 method for class 'fnets'
predict(
  object,
  newdata = NULL,
  n.ahead = 1,
  fc.restricted = TRUE,
  r = c("ic", "er"),
  ...
)
```

Arguments

`object`	`fnets` object
`newdata`	input time series matrix, with each row representing a variable; by default, uses input to `object`. Valid only for the case where `newdata` is modelled as a VAR process without any factors
`n.ahead`	forecasting horizon
`fc.restricted`	whether to forecast using a restricted or unrestricted, blockwise VAR representation of the common component
`r`	number of static factors, or a string specifying the factor number selection method when `fc.restricted = TRUE`; possible values are: • `"ic"` information criteria of Alessi, Barigozzi & Capasso (2010) • `"er"` eigenvalue ratio of Ahn & Horenstein (2013)
`...`	not used

Value

a list containing

forecast	forecasts for the given forecasting horizon
common.pred	a list containing forecasting results for the common component
idio.pred	a list containing forecasting results for the idiosyncratic component
mean.x	mean.x argument from object

See Also

fnets

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x, q = 2,
do.lrpc = FALSE, var.args = list(n.cores = 2))
pre.unr <- predict(out, fc.restricted = FALSE)
pre.res <- predict(out, fc.restricted = TRUE)
```

---

print.factor.number *Print factor number*

Description

Prints a summary of a factor.number object

Usage

```
## S3 method for class 'factor.number'
print(x, ...)
```

Arguments

x	factor.number object
...	not used

Value

NULL, printed to console

See Also

factor.number

Examples

```
library(fnets)

## Alessi, Barigozzi, and Capasso method for restricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

abc <- factor.number(x, fm.restricted = TRUE)
print(abc)
plot(abc)

## Eigenvalue ratio method
er <- factor.number(x, method = "er", fm.restricted = TRUE)
print(er)
plot(er)

## Hallin and Liška method for unrestricted models
set.seed(123)
n <- 500
p <- 50
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data * apply(idio$data, 1, sd) / apply(common$data, 1, sd) + idio$data

hl <- factor.number(x, fm.restricted = FALSE)
print(hl)
plot(hl)
```

`print.fm` *Print factor model*

Description

Prints a summary of a `fm` object

Usage

```
## S3 method for class 'fm'
print(x, ...)
```

Arguments

`x`	`fm` object
`...`	not used

Value

NULL, printed to console

See Also

fnets.factor.model

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets.factor.model(x, q = "ic")
print(out)
```

`print.fnets` *Print fnets*

Description

Prints a summary of a `fnets` object

Usage

```
## S3 method for class 'fnets'
print(x, ...)
```

Arguments

`x`	`fnets` object
`...`	not used

Value

NULL, printed to console

See Also

fnets

Examples

```
set.seed(123)
n <- 500
p <- 50
common <- sim.restricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x, q = 2,
do.lrpc = FALSE, var.args = list(n.cores = 2))
print(out)
x <- idio$data
out <- fnets.var(x,
n.cores = 2)
print(out)
```

`print.threshold` *Print threshold*

Description

Prints a summary of a `threshold` object

Usage

```
## S3 method for class 'threshold'
print(x, ...)
```

Arguments

`x`	`threshold` object
`...`	not used

Value

NULL, printed to console

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling

See Also

threshold

Examples

```
## Not run:
library(fnets)

set.seed(123)
n <- 500
p <- 20
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
   var.args = list(n.cores = 2)
)
# Granger-causal network
th1 <- threshold(out$idio.var$beta)
plot(th1)
print(th1)
# Partial correlations
th2 <- threshold(out$lrpc$pc)
# Long-run partial correlations
th3 <- threshold(out$lrpc$lrpc)

## End(Not run)
```

---

sim.restricted *Simulate data from a restricted factor model*

Description

Simulate the common component following an unrestricted factor model that admits a restricted representation; see the model (C2) in the reference.

Usage

```
sim.restricted(n, p, q = 2, heavy = FALSE)
```

Arguments

n	sample size
p	dimension
q	number of unrestricted factors; number of restricted factors is given by `2 * q`
heavy	if `heavy = FALSE`, common shocks are generated from `rnorm` whereas if `heavy = TRUE`, from `rt` with `df = 5` and then scaled by `sqrt(3 / 5)`

Value

a list containing

`data`	time series matrix with `n` rows and `p` columns
`q`	number of factors
`r`	number of restricted factors

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling

Examples

```
common <- sim.restricted(500, 50)
```

`sim.unrestricted` *Simulate data from an unrestricted factor model*

Description

Simulate the common component following an unrestricted factor model that does not admit a restricted representation; see the model (C1) in the reference.

Usage

```
sim.unrestricted(n, p, q = 2, heavy = FALSE)
```

Arguments

`n`	sample size
`p`	dimension
`q`	number of unrestricted factors
`heavy`	if `heavy = FALSE`, common shocks are generated from `rnorm` whereas if `heavy = TRUE`, from `rt` with `df = 5` and then scaled by `sqrt(3 / 5)`

Value

a list containing

`data`	time series matrix with `n` rows and `p` columns
`q`	number of factors

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series. arXiv preprint arXiv:2201.06110

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

Examples

```
common <- sim.unrestricted(500, 50)
```

`sim.var` *Simulate a VAR(1) process*

Description

Simulate a VAR(1) process; see the reference for the generation of the transition matrix.

Usage

```
sim.var(n, p, Gamma = diag(1, p), heavy = FALSE)
```

Arguments

`n`	sample size
`p`	dimension
`Gamma`	innovation covariance matrix; ignored if `heavy = TRUE`
`heavy`	if `heavy = FALSE`, common shocks are generated from `rnorm` whereas if `heavy = TRUE`, from `rt` with `df = 5` and then scaled by `sqrt(3 / 5)`

Value

a list containing

`data`	time series matrix with `n` rows and `p` columns
`A`	transition matrix
`Gamma`	innovation covariance matrix

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network estimation and forecasting for high-dimensional time series.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling

Examples

```
idio <- sim.var(500, 50)
```

threshold — *Threshold the entries of the input matrix at a data-driven level*

Description

Threshold the entries of the input matrix at a data-driven level. This can be used to perform edge selection for VAR parameter, inverse innovation covariance, and long-run partial correlation networks.

Usage

```
threshold(mat, path.length = 500)
```

Arguments

`mat`	input parameter matrix
`path.length`	number of candidate thresholds

Details

See Liu, Zhang, and Liu (2021) for more information on the threshold selection process

Value

an S3 object of class `threshold`, which contains the following fields:

`threshold`	data-driven threshold
`thr.mat`	thresholded input matrix

References

Barigozzi, M., Cho, H. & Owens, D. (2022) FNETS: Factor-adjusted network analysis for high-dimensional time series. arXiv preprint arXiv:2201.06110.

Liu, B., Zhang, X. & Liu, Y. (2021) Simultaneous Change Point Inference and Structure Recovery for High Dimensional Gaussian Graphical Models. Journal of Machine Learning Research, 22(274), 1–62.

Owens, D., Cho, H. & Barigozzi, M. (2022) fnets: An R Package for Network Estimation and Forecasting via Factor-Adjusted VAR Modelling. arXiv preprint arXiv:2301.11675.

See Also

plot.threshold, print.threshold

Examples

```
## Not run:
library(fnets)

set.seed(123)
n <- 500
p <- 20
common <- sim.unrestricted(n, p)
idio <- sim.var(n, p)
x <- common$data + idio$data
out <- fnets(x,
   var.args = list(n.cores = 2)
)
# Granger-causal network
th1 <- threshold(out$idio.var$beta)
plot(th1)
print(th1)
# Partial correlations
th2 <- threshold(out$lrpc$pc)
# Long-run partial correlations
th3 <- threshold(out$lrpc$lrpc)

## End(Not run)
```

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