Package 'mlVAR'

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Description Estimates the multi-level vector autoregression model on time-series data. Three network structures are obtained: temporal networks, contemporaneous networks and between-subjects networks.

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NeedsCompilation no

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Contents

`getNet` *Gets a network structure*

Description

This function is simply a wrapper around the plotting method for mlVAR objects, that extracts the network structure rather than plotting them.

Usage

```
getNet(x, ...)
```

Arguments

`x`	An ‘mlVAR‘ or ‘mlVARsim0‘ object.
`...`	Arguments sent to `plot.mlVAR`

Author(s)

Sacha Epskamp <mail@sachaepskamp.com>

`importMplus` *Import output from Mplus*

Description

This function imports the output from an Mplus model that has been generated by mlVAR. It can be used to make manual changes to the input file.

Usage

```
importMplus(outfile)
```

Arguments

`outfile`	Location of Mplus output file.

Author(s)

Sacha Epskamp <mail@sachaepskamp.com>

mlVAR *Multilevel VAR Estimation for Multiple Time Series*

Description

The function mlVAR computes estimates of the multivariate vector autoregression model. This model returns three stuctures: temporal effects (e.g., lag-1 regression weights), contemporaneous relationships (correlations or partial correlations) and between-subject effects (correlations and partial correlations). See details.

Usage

```
mlVAR(data, vars, idvar, lags = 1, dayvar, beepvar,
                  estimator = c("default", "lmer", "lm","Mplus"),
                  contemporaneous = c("default", "correlated",
                  "orthogonal", "fixed", "unique"), temporal =
                  c("default", "correlated", "orthogonal", "fixed",
                  "unique"), nCores = 1, verbose = TRUE, compareToLags,
                  scale = TRUE, scaleWithin = FALSE, AR = FALSE,
                  MplusSave = TRUE, MplusName = "mlVAR", iterations = "(2000)",
                  chains = nCores, signs, orthogonal
  )
```

Arguments

data	Data frame
vars	Vectors of variables to include in the analysis
idvar	String indicating the subject ID
lags	Vector indicating the lags to include
dayvar	String indicating assessment day. Adding this argument makes sure that the first measurement of a day is not regressed on the last measurement of the previous day. IMPORTANT: only add this if the data has multiple observations per day.
beepvar	Optional string indicating assessment beep per day. Adding this argument will cause non-consecutive beeps to be treated as missing!
estimator	The estimator to be used. "lmer" for sequential univariate multi-level estimation, "Mplus" for multivariate Bayesian estimation (requires Mplus), and "lm" for fixed effects estimation.
contemporaneous	How should the contemporaneous networks be estimated? These networks are always estimated post-hoc by investigating the residuals of the temporal models. "correlated" and "orthogonal" run second multi-level models in which the networks are estimated using node-wise estimation. "fixed" and "unique" simply correlate the residuals, either by computing one network for all subjects (fixed) or a single network per per subject.

temporal	How should the temporal effects be estimated? "correlated" estimates correlated random effects, "orthogonal" estimates non-correlated random effects and "fixed" estimates a model in which only the intercept is random. Defaults to "correlated" when the number of variables is less than 6 and "orthogonal" otherwise. "unique" uses lm to estimate an unique model for each subject.
nCores	Number of cores to use in computation
verbose	Logical indicating if console messages and the progress bar should be shown.
scale	Logical, should variables be standardized before estimation?
scaleWithin	Logial, should variables be scaled within-person (set to FALSE to only center within-person)
compareToLags	A vector indicating which lags to base the data on. If the model is to be compared with a model with multiple lags using mlVARcompare, this argument must be used to make sure the number of observations is the same in both models (e.g., a lag 1 model can model the second observation of a day and a lag-2 model can't, causing different number of observations and incomparable models). It is suggested to not use this argument unless you want to compare models, and always run mlVAR without using this argument afterwards in the selected model.
AR	Logical, should an auto-regression only model be fitted?
MplusSave	Logical, should the Mplus model file and output be saved?
MplusName	Name of the Mplus model file and output (without extensions)
iterations	The string used to define the number of iterations in Mplus
chains	Number of Mplus chains
signs	Optional matrix fixing the signs of contemporaneous correlations. Is estimated by running mlVAR with estimator = "lmer" if missing.
orthogonal	Deprecated argument only added for backward competability. Ignore.

Details

This function estimates the multi-level VAR model to obtain temporal, contemporaneous and between-subject effects using nodewise estimation. Temporal and between-subject effects are obtained directly from the models and contemporaneous effects are estimated post-hoc by correlating the residuals. See arxiv.org/abs/1609.04156 for details.

Setting estimator = "Mplus" will generate a Mplus model, run the analysis and read the results into R. Mplus 8 is required for this estimation. It is recommended to set contemporaneous = "fixed", though not required. For the estimation of contemporaneous random effects, the signs of contemporaneous *correlations * (not partial correlations) need be set (or estimated) via the signs argument.

Value

An mlVAR object

Author(s)

Sacha Epskamp (mail@sachaepskamp.com)

References

Bringmann, L. F., Vissers, N., Wichers, M., Geschwind, N., Kuppens, P., Peeters, F., ... & Tuerlinckx, F. (2013). A network approach to psychopathology: New insights into clinical longitudinal data. PloS one, 8(4), e60188.

Hamaker, E. L., & Grasman, R. P. (2014). To center or not to center? Investigating inertia with a multilevel autoregressive model. Frontiers in psychology, 5.

Epskamp, S., Waldorp, L. J., Mottus, R., & Borsboom, D. (2017). Discovering Psychological Dynamics: The Gaussian Graphical Model in Cross-sectional and Time-series Data. arxiv.org/abs/1609.04156.

See Also

mlVARcompare, summary.mlVAR, plot.mlVAR

Examples

```
## Not run:
### Small example ###
# Simulate data:
Model <- mlVARsim(nPerson = 50, nNode = 3, nTime = 50, lag=1)

# Estimate using correlated random effects:
fit1 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1, temporal = "correlated")

# Print some pointers:
print(fit1)

# Summary of all parameter estimates:
summary(fit1)

# Compare temporal relationships:
layout(t(1:2))
plot(Model, "temporal", title = "True temporal relationships", layout = "circle")
plot(fit1, "temporal", title = "Estimated temporal relationships", layout = "circle")

# Compare contemporaneous partial correlations:
layout(t(1:2))
plot(Model, "contemporaneous", title = "True contemporaneous relationships",
    layout = "circle")
plot(fit1, "contemporaneous", title = "Estimated contemporaneous relationships",
    layout = "circle")

# Compare between-subjects partial correlations:
layout(t(1:2))
plot(Model, "between", title = "True between-subjects relationships", layout = "circle")
plot(fit1, "between", title = "Estimated between-subjects relationships",
    layout = "circle")

# Run same model with non-correlated temporal relationships and fixed-effect model:
fit2 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "orthogonal")
fit3 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
```

```
    temporal = "fixed")

# Compare models:
mlVARcompare(fit1,fit2,fit3)

# Inspect true parameter correlation matrix:
Model$model$Omega$cor$mean
# Even though correlations are high, orthogonal model works well often!


### Large example ###
Model <- mlVARsim(nPerson = 100, nNode = 10, nTime = 100,lag=1)

# Correlated random effects no longer practical. Use orthogonal or fixed:
fit4 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "orthogonal")
fit5 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "fixed")

# Compare models:
mlVARcompare(fit4, fit5)

# Compare temporal relationships:
layout(t(1:2))
plot(Model, "temporal", title = "True temporal relationships", layout = "circle")
plot(fit4, "temporal", title = "Estimated temporal relationships", layout = "circle")

# Compare contemporaneous partial correlations:
layout(t(1:2))
plot(Model, "contemporaneous", title = "True contemporaneous relationships",
    layout = "circle")
plot(fit4, "contemporaneous", title = "Estimated contemporaneous relationships",
    layout = "circle")

# Compare between-subjects partial correlations:
layout(t(1:2))
plot(Model, "between", title = "True between-subjects relationships", layout = "circle")
plot(fit4, "between", title = "Estimated between-subjects relationships",
    layout = "circle")

## End(Not run)
```

`mlVAR-effects` *Fixed and random effects*

Description

These functions return a table of the fixed and random effects.

FUNCTIONS ARE DEPRECATED AND WILL BE REMOVED SOON.

Usage

```
fixedEffects(object, digits = 5)
randomEffects(object, digits = 5)
```

Arguments

object	A mlVAR object
digits	Number of digits to output

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mlVAR0 *Multilevel VAR Estimation for Multiple Time Series*

Description

The function mlVAR0 computes estimates of the multivariate vector autoregression model as introduced by Bringmann et al. (2013) which can be extended through treatment effects, covariates and pre- and post assessment effects.

FUNCTION IS DEPRECATED AND WILL BE REMOVED SOON.

Usage

```
mlVAR0(data, vars, idvar, lags = 1, dayvar, beepvar,
                periodvar, treatmentvar, covariates, timevar,
                maxTimeDiff, control = list(optimizer = "bobyqa"),
                verbose = TRUE, orthogonal, estimator = c("lmer",
                "lmmlasso"), method = c("default", "stepwise",
                "movingWindow"), laginteractions = c("none", "mains",
                "interactions"), critFun = BIC, lambda = 0,
                center = c("inSubject","general","none"))
```

Arguments

data	Data frame
vars	Vectors of variables to include in the analysis
idvar	String indicating the subject ID
lags	Vector indicating the lags to include
dayvar	String indicating assessment day (if missing, every assessment is set to one day)
beepvar	String indicating assessment beep per day (if missing, is added)
periodvar	String indicating the period (baseline, treatment period, etc.) of assessment (if missing, every assessment is set to one period)

treatmentvar	Character vector indicating treatment
covariates	Character indicating covariates independent of assessment.
timevar	Character indicating the time variable
maxTimeDiff	Maximum time differece to include observation pairs
control	A list of arguments sent to lmerControl
verbose	Logical to print progress to the console
orthogonal	Logical to indicate if orthogonal estimation (no correlated random effects) should be used. Defaults to FALSE if the number of nodes is less than 6 and TRUE otherwise
estimator	Estimator to use. Note: lmmlasso implementation is very experimental
method	Method to use. Experimental
laginteractions	Experimental, do not use.
critFun	Experimental, do not use.
lambda	lmmlasso lambda parameter
center	Centering to be used. "inSubject" uses within-person centering, "general" uses grand-mean centering and "none" does not use centering. IMPORTANT NOTE: "inSubject" leads to coefficients to resemble within-person slopes, the other centering option leads to coefficients to be a blend of within and between person slopes.

Details

mlVAR0 has been built to extract individual network dynamics by estimating a multilevel vector autoregression model that models the time dynamics of selected variables both within an individual and on group level. For example, in a lag-1-model each variable at time point t is regressed to a lagged version of itself at time point t-1 and all other variables at time point t-1. In psychological research, for example, this analysis can be used to relate the dynamics of symptoms on one day (as assessed by experience sampling methods) to the dynamics of these symptoms on the consecutive day.

Value

mlVAR0 returns a 'mlVAR0' object containing

fixedEffects	A matrix that contains all fixed effects coefficients with dependent variables as rows and the lagged independent variables as columns.
se.fixedEffects	A matrix that contains all standard errors of the fixed effects.
randomEffects	A list of matrices that contain the random effects coefficients.
randomEffectsVariance	A matrix containing the estimated variances between the random-effects terms
pvals	A matrix that contains p-values for all fixed effects.
pseudologlik	The pseudo log-likelihood.
BIC	Bayesian Information Criterion, i.e. the sum of all univariate models' BICs
input	List containing the names of variables used in the analysis

Author(s)

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References

Bringmann, L. F., Vissers, N., Wichers, M., Geschwind, N., Kuppens, P., Peeters, F., ... & Tuerlinckx, F. (2013). A network approach to psychopathology: New insights into clinical longitudinal data. PloS one, 8(4), e60188.

See Also

fixedEffects, fixedEffects

Examples

```
## Not run:
### Small network ###
nVar <- 3
nPerson <- 25
nTime <- 25

# Simulate model and data:
Model <- mlVARsim0(nPerson,nVar,nTime,sparsity = 0.5)

# Run mlVAR0:
Res <- mlVAR0(Model)

# Compare true fixed model with significant edges of estimated fixed model:
layout(t(1:2))
plot(Model,"fixed", title = "True model",layout="circle", edge.labels = TRUE)
plot(Res,"fixed", title = "Estimated model", layout = "circle", onlySig = TRUE,
        alpha = 0.05, edge.labels = TRUE)

# Compare true and estimated individual differences in parameters:
layout(t(1:2))
plot(Model,"fixed", title = "True model",layout="circle", edge.color = "blue",
        edge.labels = TRUE)
plot(Res,"fixed", title = "Estimated model", layout = "circle", edge.color = "blue",
        edge.labels = TRUE)

# Compare networks of subject 1:
layout(t(1:2))
plot(Model,"subject",subject = 1, title = "True model",layout="circle",
        edge.labels = TRUE)
plot(Res,"subject",subject = 1,title = "Estimated model", layout = "circle",
        edge.labels = TRUE)



### Large network ###
nVar <- 10
```

```
nPerson <- 50
nTime <- 50

# Simulate model and data:
Model <- mlVARsim0(nPerson,nVar,nTime, sparsity = 0.5)

# Run orthogonal mlVAR:
Res <- mlVAR0(Model, orthogonal = TRUE)

# Compare true fixed model with significant edges of estimated fixed model:
layout(t(1:2))
plot(Model,"fixed", title = "True model",layout="circle")
plot(Res,"fixed", title = "Estimated model", layout = "circle", onlySig = TRUE,
        alpha = 0.05)

# Compare true and estimated individual differences in parameters:
layout(t(1:2))
plot(Model,"fixed", title = "True model",layout="circle", edge.color = "blue")
plot(Res,"fixed", title = "Estimated model", layout = "circle", edge.color = "blue")

# Compare networks of subject 1:
layout(t(1:2))
plot(Model,"subject",subject = 1, title = "True model",layout="circle")
plot(Res,"subject",subject = 1,title = "Estimated model", layout = "circle")

## End(Not run)
```

`mlVAR0-methods` *print and summary functions for mlVAR0 objects*

Description

Create a short summary of an object created by `mlVAR0`.

FUNCTION IS DEPRECATED AND WILL BE REMOVED SOON.

Usage

```
  ## S3 method for class 'mlVAR0'
print(x, ...)
  ## S3 method for class 'mlVAR0'
summary(object, ...)
```

Arguments

`object`	A "mlVAR0" object
`x`	A "mlVAR0" object
`...`	Not used

Author(s)

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`mlVARcompare` *Compare mlVAR model fit*

Description

This function compares the fit of several mlVAR models. Since an mlVAR model is a combination of univariate models this function will compare the fits for each univariate model.

Usage

```
mlVARcompare(...)
```

Arguments

`...`	Any number of objects obtained from `mlVAR`

Details

Important to note is that the number of observations must be equal to make models comparable. If the lags are different and `compareToLags` was not used in `mlVAR` this function will stop with an informative error message.

Author(s)

Sacha Epskamp (mail@sachaepskamp.com)

Examples

```
## Not run:
### Small example ###
# Simulate data:
Model <- mlVARsim(nPerson = 50, nNode = 3, nTime = 50, lag=1)

# Estimate using different methods:
fit1 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "correlated")
fit2 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "orthogonal")
fit3 <- mlVAR(Model$Data, vars = Model$vars, idvar = Model$idvar, lags = 1,
    temporal = "fixed")

# Compare models:
mlVARcompare(fit1,fit2,fit3)

## End(Not run)
```

`mlVARsample` *Simulator function given an mlVAR object*

Description

Simulates data based on an mlVAR object, estimates the mlVAR network model based on the simulated data and compares the estimated network to the mlVAR object network.

Usage

```
mlVARsample(object, nTime = c(25,50,100,200), nSample = 100, pMissing = 0,
  nReps = 100, nCores = 1, ...)

## S3 method for class 'mlVARsample'
summary(object, ...)
```

Arguments

`object`	mlVAR object, or mlVARsample object in the summary method
`nTime`	Vector with number of time points to test.
`nSample`	Number of individuals in the dataset. It is possible to decrease the number of individuals compared to the individuals in the mlVAR object. However, it is not possible to have more individuals than there are in the mlVAR object.
`pMissing`	Percentage of missing data to be simulated.
`nReps`	Number of repetitions for each condition.
`nCores`	Number of cores to use.
`...`	Arguments sent to mlVAR.

Details

This function simulates data based on the mlVAR object. The individual networks (random effects) are used to simulate data using the `graphicalVARsim` function from the graphicalVAR package (Epskamp, 2020). The individual data is combined into one dataset. This dataset is used to estimate the mlVAR network.

For every condition, the function returns four values per network comparison measure (correlation, sensitivity, specificity, bias, and precision): one for the fixed temporal effects, one for the fixed contemporaneous effects, the mean comparison value of the random temporal effects, and the mean comparison value of the random contemporaneous effects.

Author(s)

Sacha Epskamp <mail@sachaepskamp.com>

References

Sacha Epskamp (2020). graphicalVAR: Graphical VAR for Experience Sampling Data. R package version 0.2.3. https://CRAN.R-project.org/package=graphicalVAR

See Also

mlVARsim, mlVAR

Examples

```
## Not run:
### Small example ###
# Simulate data:
Model <- mlVARsim(nPerson = 100, nNode = 3, nTime = 50, lag=1)

# Estimate using correlated random effects:
fit <- mlVAR(Model$Data, vars = Model$vars,
             idvar = Model$idvar, lags = 1,
             temporal = "correlated")

# Sample from fitted model:
samples <- mlVARsample(fit, nTime = 50, nSample = 50, pMissing = 0.1,
                       nReps = 5, nCores = 1)

# Summarize results:
summary(samples)

## End(Not run)
```

`mlVARsim` *Simulates an mlVAR model and data*

Description

Simulates an mlVAR model and data with a random variance-covariance matrix for the random effects.

Usage

```
mlVARsim(nPerson = 10, nNode = 5, nTime = 100, lag = 1, thetaVar = rep(1,nNode),
DF_theta = nNode * 2, mu_SD = c(1, 1), init_beta_SD = c(0.1, 1), fixedMuSD = 1,
shrink_fixed = 0.9, shrink_deviation = 0.9)
```

Arguments

`nPerson`	Number of subjects
`nNode`	Number of variables
`nTime`	Number of observations per person

lag	The maximum lag to be used
thetaVar	Contemporaneous fixed effect variances
DF_theta	Degrees of freedom in simulating person-specific contemporaneous covariances (e.g., the individual differences in contemporaneous effects)
mu_SD	Range of standard deviation for the means
init_beta_SD	Initial range of standard deviations for the temporal effects
fixedMuSD	Standard deviation used in sampling the fixed effects
shrink_fixed	Shrinkage factor for shrinking the fixed effects if the VAR model is not stationary
shrink_deviation	Shrinkage factor for shrinking the random effects variance if the VAR model is not stationary

Author(s)

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plot.mlVAR *Plot Method for mlVAR*

Description

The function plot.mlVAR plots estimated model coefficients as networks using qgraph. These can be three networks: temporal, contemporaneous and between-subjects effects, of which the latter two can be plotted as a correlation or a partial correlation network.

Usage

```
  ## S3 method for class 'mlVAR'
plot(x, type = c("temporal", "contemporaneous", "between"),
                 lag = 1, partial = TRUE, SD = FALSE, subject, order,
                 nonsig = c("default", "show", "hide", "dashed"), rule
                 = c("or", "and"), alpha = 0.05, onlySig = FALSE,
                 layout = "spring", verbose = TRUE, ...)
  ## S3 method for class 'mlVARsim'
plot(x, ...)
```

Arguments

x	An mlVAR object.
type	What network to plot?
lag	The lag to use when type = "temporal"
partial	Logical, should partial correlation matrices be plotted instead of correlation methods? Only used if type is "contemporaneous" or "between". Defaults to TRUE.

SD	Logical. Plot the standard-deviation of random effects instead of the fixed effect estimate?
subject	Subject number. If not missing, will plot the network of a specific subject instead.
order	An optional character vector used to set the order of nodes in the network.
nonsig	How to handle non-significant edges? Default will hide non-significant edges when p-values are available (fixed effects, partial correlations and temporal effects).
rule	How to choose significance in node-wise estimated GGMs (contemporaneous and between-subjects). "or" selects an edge as being significant if one node predicting the other is significant, and "and" requires both predictions to be significant.
alpha	Alpha level to test for significance
onlySig	Deprecated argument only used for backward competability.
layout	The layout argument used by qgraph
verbose	Logical, should message be printed to the console?
...	Arguments sent to qgraph

Author(s)

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`plot.mlVAR0` *Plot Method for mlVAR0*

Description

The function `plot.mlVAR0` plots estimated model coefficients as a network using `qgraph`.

FUNCTION IS DEPRECATED AND WILL BE REMOVED SOON.

Usage

```
  ## S3 method for class 'mlVAR0'
plot(x, type = c("fixed", "SD", "subject"), lag = 1,
                 subject, order, onlySig = FALSE, alpha, ...)
```

Arguments

x	A `mlVAR0` object obtained through the `mlVAR0`-function
type	Indicates whether to plot a network of fixed effects coefficients ("fixed"), the standard deviations of the random effect terms ("SD") or an individual subject's random effects network ("subject").
lag	Vector indicating the lags to include

subject	If type="subject", vector indicating the ID subject number
order	Order of nodes
onlySig	Logical. Set to TRUE to only plot significant fixed effects.
alpha	Significance level to test edges at if onlySig == TRUE. Defaults to Bonferonni corrected alpha level of 0.05 divided by the number of fixed effects.
...	Arguments sent to qgraph

Author(s)

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simulateVAR *Simulate data from VAR model*

Description

Simulates a timeseries using VAR parameters

Usage

```
simulateVAR(pars,  means = 0, lags = 1, Nt = 100, init, residuals = 0.1,
                burnin)
```

Arguments

pars	A square matrix or a list of square matrices indicating the VAR parameters
means	A vector of means.
lags	The lags to which the 'pars' argument parameters correspond. If 'pars' is a list then this argument should be a vector indicating which lags are represented by each element of the 'pars' list.
Nt	Number of time points
init	Initial setup. Must be a matrix of the first lags with rows corresponding to time points and columns corresponding to variables (e.g., if only two lags are used then the matrix must have two rows indicating the first two times points.)
residuals	Standard deviation of the residuals or a residual covariance matrix
burnin	Initial simulations not returned. Defaults to min(round(Nt/2), 100).

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summary.mlVAR *Summary of mlVAR results*

Description

Prints tables with fit indices and parameter estimates.

Usage

```
## S3 method for class 'mlVAR'
summary(object, show = c("fit", "temporal", "contemporaneous", "between"),
      round = 3, ...)
## S3 method for class 'mlVAR'
print(x, ...)
```

Arguments

object	An mlVAR object.
show	Which tables to show?
round	Number of digits.
x	An mlVAR object.
...	Not used

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