Package 'mtsdi'

April 10, 2025

Version 0.3.7

Date 2025-04-09

Depends R (>= 4.0.0),base,utils,stats,gam,splines

Title Multivariate Time Series Data Imputation

Description This is an EM algorithm based method for imputation of missing values in multivariate normal time series. The imputation algorithm accounts for both spatial and temporal correlation structures. Temporal patterns can be modeled using an ARIMA(p,d,q), optionally with seasonal components, a non-parametric cubic spline or generalized additive models with exogenous covariates. This algorithm is specially tailored for climate data with missing measurements from several monitors along a given region.

License GPL (>= 2)

NeedsCompilation no

Author Washington Junger [aut, cre],
Antonio Ponce de Leon [ctb]

Maintainer Washington Junger <wjunger@ims.uerj.br>

Repository CRAN

Date/Publication 2025-04-09 22:50:02 UTC

Contents

edaprep *Dataset Preparation for Analysis*

Description

Prepare the dataset for exploratory data analysis

Usage

```
edaprep(dataset)
```

Arguments

dataset	dataset with missing observations

Details

It replaces missing observation with the vector mean.

Value

It returns `dataset` filled in with `NA`

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput, getmean, edaprep

Examples

```
data(miss)
c <- edaprep(miss)
```

elapsedtime *Elapsed Time*

Description

Compute the elapsed time between start time and end time

Usage

```
elapsedtime(st, et)
```

Arguments

st	starting time
et	ending time

Details

It returns the time the process took to run.

Value

String of the form hh:mm:ss

Note

It is not intended to be called directly.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput

getmean *Row Means Estimates*

Description

Estimate the row mean from a mtsdi object regarding a fixed number of imputed values

Usage

```
getmean(object, weighted=TRUE, mincol=1, maxconsec=3)
```

Arguments

object	imputation object
weighted	If TRUE, weights returned by mnimput will be used form mean computation
mincol	integer for the minimun number of valid values by row
maxconsec	integer for the maximum number of consecutive missing values in a column

Details

It is useful just in case one wants row mean estimated. If log tranformation was used, mean is adjusted accordingly.

Value

A vector of of rows mean with length n, where n is the number of observations.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput, getmean, edaprep

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
m <- getmean(i,2)
```

miss *Sample Dataset*

Description

A small sample dataset for the tutorial on data imputation

Usage

```
data(miss)
```

Format

A data frame with 24 observations on the following 5 variables.

`c31` a numeric vector with 1 missing observation

`c32` a numeric vector with 1 missing observation

`c33` a numeric vector with 6 missing observations

`c34` a numeric vector with 3 missing observations

`c35` a numeric vector with 3 missing observations

Examples

```
data(miss)
```

mkjnw *Example from Johnson and Wichern's Book*

Description

Create a data matrix from the Johnson and Wichern's book

Usage

```
mkjnw()
```

Details

This function creates a data matrix from the Johnson & Wichern's book.

Value

It returns a data matrix.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

See Also

mnimput

Examples

```
d <- mkjnw()
```

---

mnimput *Multivariate Normal Imputation*

Description

Perform the modified EM algorithm imputation on a normal multivariate dataset

Usage

```
mnimput(formula, dataset, by = NULL, log = FALSE, log.offset = 1,
eps = 1e-3, maxit = 1e2, ts = TRUE, method = "spline",
sp.control = list(df = NULL, weights = NULL), ar.control =
list(order = NULL, period = NULL), ga.control = list(formula,
weights = NULL), f.eps = 1e-6, f.maxit = 1e3, ga.bf.eps = 1e-6,
ga.bf.maxit = 1e3, verbose = FALSE, digits = getOption("digits"))
```

Arguments

formula	formula indicating the missing data frame, for instance, ~X1+X2+X3+...+Xp
dataset	data with missing values to be imputated
by	factor for variance windows. Default is NULL for a single variance matrix
log	logical. If TRUE data will be transformed into log scale. Default is FALSE
log.offset	If log is TRUE, log values will be shifted by this offset. Default is 1
eps	stop criterion
maxit	maximum number of iterations
ts	logical. TRUE if is time series
method	method for univariate time series filtering. It may be smooth, gam or arima. See Details
sp.control	list for Spline smooth control. See Details

ar.control	list for ARIMA fitting control. See Details
ga.control	list for GAM fitting control. See Details
f.eps	convergence criterion for the ARIMA filter. See arima
f.maxit	maximum number of iterations for the ARIMA filter. See arima
ga.bf.eps	covergence criterion for the backfitting algorithm of GAM models. See gam
ga.bf.maxit	maximum number of iterations for the backfitting algorithm of GAM models. See gam
verbose	if TRUE convergence information on each iteration is printed. Default is FALSE
digits	an integer indicating the decimal places. If not supplied, it is taken from options

Details

This is a modified version of the EM algorithm for imputation of missing values. It is also applicable to time series data. When it is explicited the time series attribute through the argument ts, missing values are estimated accounting for both correlation between time series and time structure of the series itself. Several filters can be used for prediction of the mean vector in the E-step.

One can select the method for the univariate time series filtering by the argument method. The default method is "spline". In this case a smooth spline is fitted to each of the time series at each iteration. Some parameters can be passed to smooth.spline through sm.control. df is a vector as long as the number of columns in dataset holding fixed degrees of freedom of the splines. If NULL, the degrees of freedom of each spline are chosen by cross-validation. If df has length 1, this values is recycled for all the covariates. weights must be a matrix of the same size of dataset with the weights for smooth.spline. If NULL, all the observations will have weights equal to 1.

Other possibity for time series filtering is to fitting an ARIMA model for each of the time series by setting method to "arima". The ARIMA models must be identified before using this function, nonetheless. arima function can be partially controlled through ar.control. Each column of order must hold the corresponding (p, d, q) parameters for each univariate time series if period is NULL. If period is not NULL, order must also hold the multiplicative seasonality parameters, so each column of order takes the form (p, d, q, P, D, Q). period is the multiplicative seasonality period. f.eps and f.maxit control de convergence of the ARIMA fitting algorithm. Convergence problems due non stationarity may arise when using this option.

Last but not least, a very interesting approach to modelling temporal patterns is using a full fledged regression model. It is possible to use generalised aditive (or linear) models with exogenous variates to proper filtering of time patterns. One must set method to gam and supply a vector of formulas in ga.control. One must supply one formula for each covariate. Using covariates that are part of the formula of the imputation model may yield some colinearity among the variates. See gam and glm for details. In order to use regression models for the level, set method to "gam"

Simulations have shown that the algorithm is stable and yields good results on imputation of normal data.

Value

The function returns an object of class mtsdi containing

call	function call
dataset	imputed dataset

muhat	estimated mean vector
sigmahat	estimated covariance matrix
missings	vector holding the number of missing values on each row
iterations	number of iterations until convergence or reach maxit
convergence	convergence value. See Details
converged	a logical indicating if the algorithm converged
time	elapsed time of the process

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. Atmospheric Environment, 102, 96-104.

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.

McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.

Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.

Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also

mnimput, predict.mtsdi, edaprep

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
## one-window covariance
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(i)

## two-window covariances
b<-c(rep("year1",12),rep("year2",12))
ii <- mnimput(f,miss,by=b,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(ii)
```

`mstats` *Missing Dataset Statistics*

Description

Carry out some statistics from the incomplete dataset

Usage

```
mstats(dataset)
```

Arguments

`dataset`	dataset with missing for description

Details

This function computes the proportion of missing observations in a given dataset by rows and columns.

Value

A list containing

`rows`	number of missing in each row
`columns`	number of missing in each column
`pattern`	the pattern of the missing values

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

`mnimput`, `getmean`, `edaprep`

Examples

```
data(miss)
mstats(miss)
```

plot.mtsdi *Plot the Imputed Matrix*

Description

This function produces a plot with imputed values and the estimated level for each of the columns in the imputed matrix.

Usage

```
## S3 method for class 'mtsdi'
plot(x, vars = "all", overlay = TRUE, level = TRUE,
points = FALSE, leg.loc = "topright", horiz = FALSE, at.once = FALSE, ...)
```

Arguments

x	an object of the class mtsdi
vars	a vector with de variables to plot
overlay	logical. If TRUE, observed values are plot over the imputed ones
level	logical. If TRUE, the level is plot
points	logical. If TRUE, points on the observed and imputed values are plot
leg.loc	a list with x and y coordinates for the legend or a quoted string. Default is "topright". See Details
horiz	logical. If TRUE, the legend will horizontal oriented
at.once	logical. If TRUE, all the variables are plot in separate windows at once
...	further options for function plot

Details

The leg.loc option may also be specified by setting one of the following quoted strings "bottomright", "bottom", "bottomleft", "left", "topleft", "top", "topright", "right", or "center". This places the legend on the inside of the plot frame at the given location with the orietation set by horiz. See legend for further details.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
plot(i)
```

`predict.mtsdi` *Imputed Dataset Extraction*

Description

Extract imputed dataset from a `mtsdi` object

Usage

```
## S3 method for class 'mtsdi'
predict(object, ...)
```

Arguments

`object`	imputation object
`...`	further options passed to the generic function `predict`

Details

If log tranformation was used, dataset is back transformed accordingly.

Value

A vector of of rows mean with lenght n, where n is the number of observations.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. Atmospheric Environment, 102, 96-104.

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.

McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.

Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.

Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also

mnimput, getmean, edaprep

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
predict(i)
```

`print.mtsdi` *Print Model Output*

Description

Printing method for the imputation model

Usage

```
## S3 method for class 'mtsdi'
print(x, digits = getOption("digits"), ...)
```

Arguments

`x`	an object of class `summary.mtsdi`
`digits`	an integer indicating the decimal places. If not supplied, it is taken from `options`
`...`	further options passed to `print`

Value

This function does not return a value.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
print(i)
```

print.summary.mtsdi *Print Summary*

Description

Printing method for the summary

Usage

```
## S3 method for class 'summary.mtsdi'
print(x, digits = getOption("digits"),  print.models = TRUE, ...)
```

Arguments

x	an object of class summary.mtsdi
print.models	a logical indicating that time filtering models should also be printed
digits	an integer indicating the decimal places. If not supplied, it is taken from options
...	further options passed from summary.mtsdi

Value

This function does not return a value.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

mnimput

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(i)
```

summary.mtsdi *Summary Information*

Description

Print summary information on the imputation object

Usage

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

Arguments

object	an object of class mtsdi
...	further options passed to print.summary.mtsdi

Value

The function resturns a list containing

call	function call
muhat	estimated mean vector
sigmahat	estimated covariance matrix
iterations	number of iterations used
convergence	relative difference of covariance determinant reached
time	time used in the process
models	details on the models used for time filtering
log	a logical indicating that data are log transformed
log.offset	offset used in the log transformation in order to avoid zeros

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. Atmospheric Environment, 102, 96-104.

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.

McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.

Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.

Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also

mnimput, predict

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(i)
```

Index