Package ‘forecTheta’

May 26, 2016

Type Package

Title Forecasting Time Series by Theta Models

Version 2.2

Date 2016-05-25

Author Jose Augusto Fiorucci, Francisco Louzada and Bao Yiqi

Maintainer Jose Augusto Fiorucci <jafiorucci@gmail.com>

BugReports Send an email for <jafiorucci@gmail.com> with title
'forecTheta Bug'

Depends R (>= 2.0), parallel, forecast, tseries

Description
Routines for forecasting univariate time series using Theta Models. Contains several cross-validation routines.

License GPL (>= 2)

URL http://arxiv.org/abs/1503.03529

NeedsCompilation no

Repository CRAN

Date/Publication 2016-05-26 09:21:12

R topics documented:

Cross Validation *Generalised Rolling Origin Evaluation*

Description

This function implements the Generalised Rolling Origin Evaluation of Fioruci et al (2015). Its particular cases include the cross validation methods: Rolling Origin Evaluation and Fixed Origin Evaluation of Tashman(2000).

Usage

```
groe(y, forecFunction, g="sAPE", n1=length(y)-10, m=5,
        H=length(y)-n1, p=1+floor((length(y)-n1)/m), ...)

rolOrig(y, forecFunction, g="sAPE", n1=length(y)-10, ...)

fixOrig(y, forecFunction, g="sAPE", n1=length(y)-10, ...)
```

Arguments

`y`	Object of time series class or a vector
`forecFunction`	A forecasting method as one object of the `forecast` class of forecast package.
`g`	The prediction error type of `errorMetric` function. The possible values are `"sAPE"`, `"APE"`, `"AE"` and `"SE"`.
`n1`	The index of the first origin element.
`m`	The number of movements of the origin in each update.
`H`	The number of predictions forward of each origin.
`p`	The number of origin updates. Default is the maximum.
`...`	Additional arguments for `forecFunction`.

Details

If `m=1` is computed the Rolling Origin Evaluation. If `m>=length(y)-n1` is computed the Fixed Origin Evaluation.

Value

The sum of the prediction errors.

Note

The `otm.arxiv` function use this function for estimate the theta parameter when the `theta` argument is `NULL`. Your computer may go into an infinite looping if you use `forecFunction = otm.arxiv` without specific a numeric value for the `theta` argument.

Author(s)

Jose Augusto Fiorucci and Francisco Louzada

References

Fioruci J.A., Pellegrini T.R., Louzada F., Petropoulos F. (2015). *The Optimised Theta Method*. Free available at http://arxiv.org/abs/1503.03529.

Tashman, L.J. (2000). *Out-of-sample tests of forecasting accuracy: an analysis and review*. International Journal of Forecasting 16 (4), 437–450.

See Also

forecTheta-package, dotm, otm.arxiv

Examples

```
y1 = 2+ 0.15*(1:20) + rnorm(20,2)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30,2)
y =  as.ts(c(y1,y2))

## Rolling Origin Evaluation
rolOrig( y=y, forecFunction = dotm, n1=40)
rolOrig( y=y, forecFunction = expSmoot, n1=40)
rolOrig( y=y, forecFunction = stheta, n1=40)
rolOrig( y=y, forecFunction = otm.arxiv, n1=40, theta=3)

## Fixed Origin Evaluation
fixOrig( y=y, forecFunction = dotm, n1=40)
fixOrig( y=y, forecFunction = expSmoot, n1=40)
fixOrig( y=y, forecFunction = stheta, n1=40)
fixOrig( y=y, forecFunction = otm.arxiv, n1=40, theta=3)

## Generalised Rolling Origin Evaluation with two origin updates.
## Where the first is the 40th element and second is the 45th element
groe( y=y, forecFunction = dotm, m=5, n1=40)
groe( y=y, forecFunction = expSmoot, m=5, n1=40)
groe( y=y, forecFunction = stheta, m=5, n1=40)
groe( y=y, forecFunction = otm.arxiv, m=5, n1=40, theta=3)
```

Error Metric — *Error Metric Function*

Description

This function implements some of the more used error metrics. These metrics are "sMAPE", "MAPE", "MAE", "MSE" and they respectively versions with median "sMdAPE", "MdAPE", "MdAE", "MdSE".

Usage

```
errorMetric(obs, forec, type="sAPE", statistic="M")
```

Arguments

`obs`	A vector or a matrix with the real values.
`forec`	A vector or a matrix with the estimated values.
`type`	The error type of "sAPE", "APE", "AE" and "SE".
`statistic`	The statistic to be returned. Use "M" or "Md" for return the mean or median of the errors. If "N" so a vector with all errors will be returned.

Details

The metric sMAPE is obtained using `type = "sAPE"` and `statistic = "M"`

The metric sMdAPE is obtained using `type = "sAPE"` and `statistic = "Md"`

The metric MAPE is obtained using `type = "APE"` and `statistic = "M"`

The metric MdAPE is obtained using `type = "APE"` and `statistic = "Md"`

The metric MAE is obtained using `type = "AE"` and `statistic = "M"`

The metric MdAE is obtained using codetype = "AE" and `statistic = "Md"`

The metric MSE is obtained using `type = "SE"` and `statistic = "M"`

The metric MdSE is obtained using `type = "SE"` and `statistic = "Md"`

Value

If `statistic="M"` or `statistic="Md"` it is returned the respectively error metric result. If `statistic="N"` so is returned a vector with all errors points according to the chosen error type.

Author(s)

Jose Augusto Fiorucci and Francisco Louzada

See Also

forecTheta-package, groe

Examples

```
##############################################################

y1 = 2+ 0.15*(1:20) + rnorm(20,2)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30,2)
y =  as.ts(c(y1,y2))

out <- dotm(y=as.ts(y[1:40]), h=10)

### sMAPE metric
errorMetric(obs=as.ts(y[41:50]), forec=out$mean)
```

```
### sMdAPE metric
errorMetric(obs=as.ts(y[41:50]), forec=out$mean, statistic = "Md")

### MASE metric
meanDiff1 = mean(abs(diff(as.ts(y[1:40]), lag = 1)))
errorMetric(obs=as.ts(y[41:50]), forec=out$mean, type = "AE", statistic = "M") / meanDiff1
```

`expSmoot` *Simple Exponential Smoothing Method*

Description

Estimation of Simple Exponential Smoothing Method

Usage

```
expSmoot(y, h=5, ell0=NULL, alpha=NULL, lower = c(-1e+10, 0.1),
upper = c(1e+10, 0.99))
```

Arguments

`y`	Object of time series class.
`h`	Number of required forecasting periods.
`ell0`	The value of `ell0^*` parameter.
`alpha`	The value of `alpha` parameter.
`lower`	The lower limit of parametric space.
`upper`	The upper limit of parametric space.

Value

A list containing the elements:

`$y`	The original time series.
`$par`	The estimated values for `(ell^*, alpha)` parameters
`$mean`	The forecasting values
`$fitted`	A time series element with the fitted points.
`$residuals`	A time series element with the residual points.

Author(s)

Jose Augusto Fiorucci, Francisco Louzada and Bao Yiqi

See Also

`forecTheta-package`, `stheta`, `dotm`

Examples

```
y1 = 2+ 0.15*(1:20) + rnorm(20,2)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30,2)
y =  as.ts(c(y1,y2))

expSmoot(y, h=10)
```

---

forecTheta-Package *Forecasting Time Series by Theta Models*

Description

In this package we implement functions for forecast univariate time series using the several Theta Models (Fiorucci et al, 2015 and 2016) and the Standard Theta Method of Assimakopoulos \& Nikolopoulos (2000). Moreover, it is including a function for compute the main errors metrics used in time series forecasting and a function for compute the Generalised Rolling Origin Evaluation, which contain as particular cases the Rolling Origin Evaluation and the Fixed Origin Evaluation of Tashman (2000).

Details

Package:	forecTheta
Type:	Package
Version:	2.2
Date:	2016-05-25
License:	GPL (>=2.0)

```
dotm(y, h)
stheta(y, h)
errorMetric(obs, forec, type = "sAPE", statistic = "M")
groe(y, forecFunction = ses, g = "sAPE", n1 = length(y)-10)
```

Author(s)

Jose Augusto Fiorucci, Francisco Louzada and Bao Yiqi

Maintainer: Jose Augusto Fiorucci <jafiorucci@gmail.com>

References

Fiorucci J.A., Pellegrini T.R., Louzada F., Petropoulos F., Koehler, A. (2016). *Models for optimising the theta method and their relationship to state space models*, International Journal of Forecasting. Accepted Paper. https://www.researchgate.net/publication/294420765_Models_for_optimising_the_theta_method_and_their_relationship_to_state_space_models

Fiorucci J.A., Pellegrini T.R., Louzada F., Petropoulos F. (2015). *The Optimised Theta Method*. Free available at http://arxiv.org/abs/1503.03529.

Assimakopoulos, V. and Nikolopoulos k. (2000). *The theta model: a decomposition approach to forecasting*. International Journal of Forecasting 16, 4, 521–530.

Tashman, L.J. (2000). *Out-of-sample tests of forecasting accuracy: an analysis and review*. International Journal of Forecasting 16 (4), 437–450.

See Also

dotm, stheta, otm.arxiv, groe, rolOrig, fixOrig, errorMetric

Examples

```
##############################################################

y1 = 2+ 0.15*(1:20) + rnorm(20)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30)
y =  as.ts(c(y1,y2))
out <- dotm(y, h=10)
summary(out)
plot(out)

out <- dotm(y=as.ts(y[1:40]), h=10)
summary(out)
plot(out)

out2 <- stheta(y=as.ts(y[1:40]), h=10)
summary(out2)
plot(out2)

### sMAPE metric
errorMetric(obs=as.ts(y[41:50]), forec=out$mean, type = "sAPE", statistic = "M")
errorMetric(obs=as.ts(y[41:50]), forec=out2$mean, type = "sAPE", statistic = "M")

### sMdAPE metric
errorMetric(obs=as.ts(y[41:50]), forec=out$mean, type = "sAPE", statistic = "Md")
errorMetric(obs=as.ts(y[41:50]), forec=out2$mean, type = "sAPE", statistic = "Md")

### MASE metric
meanDiff1 = mean(abs(diff(as.ts(y[1:40]), lag = 1)))
errorMetric(obs=as.ts(y[41:50]), forec=out$mean, type = "AE", statistic = "M") / meanDiff1
errorMetric(obs=as.ts(y[41:50]), forec=out2$mean, type = "AE", statistic = "M") / meanDiff1

#### cross validation (2 origins)
#groe( y=y, forecFunction = otm.arxiv, m=5, n1=40, p=2, theta=5)
#groe( y=y, forecFunction = stheta, m=5, n1=40, p=2)

#### cross validation (rolling origin evaluation)
#rolOrig( y=y, forecFunction = otm.arxiv, n1=40, theta=5)
#rolOrig( y=y, forecFunction = stheta, n1=40)
```

otm.arxiv *Optimised Theta Method*

Description

Functions for forecast univariate time series using the Optimised Theta Method presented in the arxiv paper (Fioruci et al, 2015). If the theta parameter is not specified so the Generalised Rolling Origin Evaluation is used for select the theta value over the thetaList argument.

Usage

```
otm.arxiv( y, h=5, s=NULL, theta=NULL, tLineExtrap=expSmoot, g="sAPE",
approach="c", n1=NULL, m=NULL, H=NULL, p=NULL,
thetaList=seq(from=1,to=5,by=0.5), mc.cores=1, ...)
```

Arguments

`y`	Object of time series class
`h`	Number of required forecasting periods
`s`	If `TRUE`, the multiplicative seasonal decomposition is used. If `NULL`, quarterly and monthly time series are tested for statistically seasonal behaviour, with 95% of significance. Default is NULL.
`theta`	The value of theta parameter. If `theta = NULL` the theta parameter is estimated using the Generalised Rolling Origin Evaluation.
`tLineExtrap`	A forecasting function for extrapolation the second theta-line. Default is `expSmoot`.
`g`	The error type that will be used by `groe` function for select the `theta` value in the estimation process. The possibility values for `g` is `"sAPE", "APE", "AE"` and `"SE"`. If `theta` is not `NULL` the `g` argument is not used. Default is "sAPE".
`approach`	The approach set-up for `groe` parameters (`n1, m, H, p`). One letter between `'a'` to `'h'` according to Fioruci et al (2015).
`n1`	The first origin for Generalised Rolling Origin Evaluation. This argument is not used if `theta!=NULL` or `approach!=NULL`.
`m`	The number of movements of the origin in each step. This argument is not used if `theta!=NULL` or `approach!=NULL`.
`H`	The number of predictions in each step. This argument is not used if `theta!=NULL` or `approach!=NULL`.
`p`	The number of origin updates. This argument is not used if `theta!=NULL` or `approach!=NULL`.
`thetaList`	A vector with the possible values for `theta`. This argument is not used if `theta` argument is not `NULL`.
`mc.cores`	Number of cores that will be used for estimate the theta parameter. It is not accepted `mc.cores>1` on Windows SO.
`...`	Additional arguments for `tLineExtrap`.

Details

These functions are fully automatic, you just need to pass your time series. Particular cases are obtained by: If `theta = 1` the `tLineExtrapModel` method is computed; If `theta = 2` so the Standard Theta Method of Assimakopoulos and Nikolopoulos (2000) is computed.

By default (`s=NULL`), the 90% significance seasonal Z-test, used by Assimakopoulos and Nikolopoulos (2000), is applied for quarterly and monthly time series.

Value

An list containing the elements:

`$y`	The original time series.
`$mean`	A time series element with the forecasting points.
`$fitted`	A time series element with the fitted points.
`$residuals`	A time series element with the residual points.
`$theta`	The estimated theta value.
`$tLineExtrap_par`	The estimated parameters of `tLineExtrap` method.
`$weights`	The estimated weights values.

Note

The `thetaM` function is just a particular case of `otm` with `theta=2`.

Author(s)

Jose Augusto Fiorucci, Francisco Louzada and Bao Yiqi

References

Fioruci J.A., Pellegrini T.R., Louzada F., Petropoulos F. (2015). *The Optimised Theta Method*. Free available at http://arxiv.org/abs/1503.03529.

Assimakopoulos, V. and Nikolopoulos k. (2000). *The theta model: a decomposition approach to forecasting*. International Journal of Forecasting 16, 4, 521-530.

See Also

forecTheta-package, dotm, groe

Examples

```
y1 = 2+ 0.15*(1:20) + rnorm(20,2)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30,2)
y =  as.ts(c(y1,y2))

otm.arxiv(y, h=10)
```

```
### running the M3-competition data base by OTM approach (a) ###
#require(Mcomp)
#data(M3)
#
#forec = matrix(NA, nrow=3003, ncol=18)
#obs = matrix(NA, nrow=3003, ncol=18) #matrix of the out-sample values
#
#for(i in 1:3003){
# if(i %% 100 == 0){print(i)}
# x=M3[[i]]$x
# h=M3[[i]]$h
# out = otm.arxiv(x,h,approach='a',tLineExtrap=ses)
# forec[i,1:h] = out$mean
# obs[i,1:h] = M3[[i]]$xx
#}
#
#sAPE = errorMetric(obs, forec, type="sAPE", statistic="N") ## sAPE matrix
#
##### sMAPE results ##
### Yearly
#mean( sAPE[1:645, 1:6] )
### QUARTERLY
#mean( sAPE[646:1401, 1:8] )
### MONTHLY
#mean( sAPE[1402:2829, 1:18] )
### Other
#mean( sAPE[2830:3003, 1:8] )
### ALL
#mean( sAPE, na.rm=TRUE )
```

`Plot` *Plot forecasts points and prediction intervals for* `thetaModel` *objects*

Description

Produces a figure of the time series and the forecasts points from Optimised Theta Method.

Usage

```
## S3 method for class 'thetaModel'
plot(x, ylim=NULL, xlim=NULL, ylab=NULL, xlab=NULL, ...)
```

Arguments

`x`	Object of class “thetaModel”.
`ylim`	the y limits of the plot.
`xlim`	the x limits of the plot.
`ylab`	a label for the y axis.

`xlab`	a label for the x axis.
`...`	Other plotting parameters passed to `par`.

Value

None. Function produces a plot

Author(s)

Jose A Fiorucci

See Also

`dotm`, `forecTheta-package`

Examples

```
y1 = 2+ 0.15*(1:20) + rnorm(20,2)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30,2)
y =  as.ts(c(y1,y2))
out <- dotm(y, h=10)
plot(out)
```

`Theta Models` *Theta Models*

Description

Functions for forecast univariate time series using the Dynamic Optimised Theta Model, Dynamic Standard Theta Model, Optimised Theta Model and Standard Theta Model (Fiorucci et al, 2016). We also provide an implementation for the Standard Theta Method (STheta) of Assimakopoulos and Nikolopoulos (2000).

Usage

```
dotm(y, h=5, level=c(80,90,95), s=NULL, par_ini=c(y[1]/2, 0.5, 2),
estimation=TRUE, lower=c(-1e+10, 0.1, 1.0), upper=c(1e+10, 0.99, 1e+10),
opt.method="Nelder-Mead")

dstm(y, h=5, level=c(80,90,95), s=NULL, par_ini=c(y[1]/2, 0.5), estimation=TRUE,
lower=c(-1e+10, 0.1), upper=c(1e+10, 0.99), opt.method="Nelder-Mead")

otm(y, h=5, level=c(80,90,95), s=NULL, par_ini=c(y[1]/2, 0.5, 2),
estimation=TRUE, lower=c(-1e+10, 0.1, 1.0), upper=c(1e+10, 0.99, 1e+10),
opt.method="Nelder-Mead")

stm(y, h=5, level=c(80,90,95), s=NULL, par_ini=c(y[1]/2, 0.5), estimation=TRUE,
lower=c(-1e+10, 0.1), upper=c(1e+10, 0.99), opt.method="Nelder-Mead")

stheta(y, h=5, s=NULL)
```

Arguments

`y`	Object of time series class.
`h`	Number of required forecasting periods.
`level`	Levels for prediction intervals.
`s`	If `TRUE`, the multiplicative seasonal decomposition is used. If `NULL` and `frequency(y)>=4` the time series is tested for statistically seasonal behaviour, with 90% of significance. If s='additive' or close zero values been find in the multiplicative decomposition, the additive decomposition is performed hatter than multiplicative. Default is NULL.
`par_ini`	Vector of initialization for `(ell, alpha, theta)` parameters.
`estimation`	If `TRUE`, the `optim()` function is consider for compute the minimum square estimator of parameters. If `FALSE`, the models/methods are computed for `par_ini` values.
`lower`	The lower limit of parametric space.
`upper`	The upper limit of parametric space.
`opt.method`	The numeric optimisation method for `optim()` function. Choose one among `'Nelder-Mead', 'L-BFGS-B', 'SANN'`.

Details

By default (`s=NULL`), the 90% significance seasonal Z-test, used by Assimakopoulos and Nikolopoulos (2000), is applied for quarterly and monthly time series.

For details of each model see Fiorucci et al, 2016. If you are looking for the methods presented in the arXiv paper (Fiorucci et al, 2015), see `otm.arxiv()` function.

Value

An object of `thetaModel` class with one list containing the elements:

`$method`	The name of the model/method
`$y`	The original time series.
`$s`	A binary indication for seasonal decomposition.
`type`	Classical seasonal decomposition type.
`opt.method`	The optimisation method used in the `optim()` function.
`$par`	The estimated values for `(ell, alpha, theta)` parameters
`$weights`	The estimated weights values.
`$fitted`	A time series element with the fitted points.
`$residuals`	A time series element with the residual points.
`$mean`	The forecasting values.
`$level`	The levels for prediction intervals.
`$lower`	Lower limits for prediction intervals.
`$upper`	Upper limits for prediction intervals.
`$tests`	The p.value of Teraesvirta Neural Network test applied on unseasoned time series and the p.value of Shapiro-Wilk test applied on unseasoned residuals.

Author(s)

Jose Augusto Fiorucci, Francisco Louzada and Bao Yiqi

References

Fiorucci J.A., Pellegrini T.R., Louzada F., Petropoulos F., Koehler, A. (2016). *Models for optimising the theta method and their relationship to state space models*, International Journal of Forecasting. Accepted Paper. https://www.researchgate.net/publication/294420765_Models_for_optimising_the_theta_method_and_their_relationship_to_state_space_models

Fiorucci J.A., Pellegrini T.R., Louzada F., Petropoulos F. (2015). *The Optimised Theta Method*. Free available at http://arxiv.org/abs/1503.03529.

Assimakopoulos, V. and Nikolopoulos k. (2000). *The theta model: a decomposition approach to forecasting*. International Journal of Forecasting 16, 4, 521-530.

See Also

forecTheta-package, otm.arxiv

Examples

```
y1 = 2+ 0.15*(1:20) + rnorm(20)
y2 = y1[20]+ 0.3*(1:30) + rnorm(30)
y =  as.ts(c(y1,y2))
out <- dotm(y, h=10)
summary(out)
plot(out)

#### additive seasonal decomposition ###
x = sin(2*pi*seq(0,9,len=300)) + exp((1:300)/150) + rnorm(mean=0,sd=0.5,n=300)
y = ts(x, frequency=33)
out <- dotm(y, h=50, s='additive')
summary(out)
plot(out)

######### Reproducing the M3 results by DOTM ############
# library(Mcomp)
# data(M3)
#
# forec = matrix(NA, nrow=3003, ncol=18)
# obs = matrix(NA, nrow=3003, ncol=18) #matrix of the out-sample values
# meanDiff <- rep(1, 3003)
#
# for(i in 1:3003){
#  if(i %% 100 == 0){print(i);}
#  x=M3[[i]]$x
#  h=M3[[i]]$h
#  out = dotm(x,h,level=NULL)
#  forec[i,1:h] = out$mean
#  obs[i,1:h] = M3[[i]]$xx
```

```
#  meanDiff[i] = mean(abs(diff(x, lag = frequency(x))))
# }

############## sMAPE ###################
# sAPE_matrix = errorMetric(obs=obs, forec=forec, type="sAPE", statistic="N")
#### Yearly ###
# mean( sAPE_matrix[1:645, 1:6] )
#### QUARTERLY ###
# mean( sAPE_matrix[646:1401, 1:8] )
#### MONTHLY ###
# mean( sAPE_matrix[1402:2829, 1:18] )
#### Other ###
# mean( sAPE_matrix[2830:3003, 1:8] )
#### ALL ###
# mean( sAPE_matrix, na.rm=TRUE )
#
############# MASE ######################
# AE_matrix = errorMetric(obs=obs, forec=forec, type="AE", statistic="N")
#   ASE_matrix=AE_matrix/meanDiff
#### Yearly ###
# mean( ASE_matrix[1:645, 1:6] )
#### QUARTERLY ###
# mean( ASE_matrix[646:1401, 1:8] )
#### MONTHLY ###
# mean( ASE_matrix[1402:2829, 1:18] )
#### Other ###
# mean( ASE_matrix[2830:3003, 1:8] )
#### ALL ###
# mean( ASE_matrix, na.rm=TRUE )
########################################################
```

Index