

# Package ‘forecastHybrid’

May 4, 2018

**Title** Convenient Functions for Ensemble Time Series Forecasts

**Version** 2.2.12

**Date** 2018-05-04

**Description** Convenient functions for ensemble forecasts in R combining approaches from the 'forecast' package. Forecasts generated from `auto.arima()`, `ets()`, `thetam()`, `nnetar()`, `stlm()`, and `tbatst()` can be combined with equal weights, weights based on in-sample errors, or CV weights. Cross validation for time series data and user-supplied models and forecasting functions is also supported to evaluate model accuracy.

**Depends** R (>= 3.1.1), forecast (>= 8.1),

**Imports** doParallel (>= 1.0.10), foreach (>= 1.4.3), ggplot2 (>= 2.2.0), zoo (>= 1.7)

**Suggests** GMDH, knitr, rmarkdown, roxygen2, testthat

**VignetteBuilder** knitr

**License** GPL-3

**URL** <https://github.com/ellisp/forecastHybrid>

**BugReports** <https://github.com/ellisp/forecastHybrid/issues>

**LazyData** true

**RoxygenNote** 6.0.1

**ByteCompile** true

**NeedsCompilation** no

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**Repository** CRAN

**Date/Publication** 2018-05-04 14:19:45 UTC

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accuracy.cvts	<i>Accuracy measures for cross-validated time series</i>
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---

**Description**

Returns range of summary measures of the cross-validated forecast accuracy for cvts objects.

**Usage**

```
## S3 method for class 'cvts'
accuracy(f, ...)
```

**Arguments**

f	a cvts object created by <a href="#">cvts</a> .
...	other arguments (ignored).

**Details**

Currently the method only implements ME, RMSE, and MAE. The accuracy measures MPE, MAPE, and MASE are not calculated. The accuracy is calculated for each forecast horizon up to `maxHorizon`

**Author(s)**

David Shaub

---

accuracy.hybridModel *Accuracy measures for hybridModel objects*

---

### Description

Accuracy measures for hybridModel objects.

### Usage

```
## S3 method for class 'hybridModel'  
accuracy(f, individual = FALSE, ...)
```

### Arguments

f	the input hybridModel.
individual	if TRUE, return the accuracy of the component models instead of the accuracy for the whole ensemble model.
...	other arguments (ignored).

### Details

Return the in-sample accuracy measures for the component models of the hybridModel

### Value

The accuracy of the ensemble or individual component models.

### Author(s)

David Shaub

### See Also

[accuracy](#)

**Description**

Perform cross validation on a time series.

**Usage**

```
cvts(x, FUN = NULL, FCFUN = NULL, rolling = FALSE, windowSize = 84,
     maxHorizon = 5, horizonAverage = FALSE, xreg = NULL,
     saveModels = ifelse(length(x) > 500, FALSE, TRUE),
     saveForecasts = ifelse(length(x) > 500, FALSE, TRUE), verbose = TRUE,
     num.cores = 2L, extraPackages = NULL, ...)
```

**Arguments**

x	the input time series.
FUN	the model function used. Custom functions are allowed. See details and examples.
FCFUN	a function that process point forecasts for the model function. This defaults to <a href="#">forecast</a> . Custom functions are allowed. See details and examples. See details.
rolling	should a rolling procedure be used? If TRUE, nonoverlapping windows of size maxHorizon will be used for fitting each model. If FALSE, the size of the dataset used for training will grow by one each iteration.
windowSize	length of the window to build each model. When rolling == FALSE, the each model will be fit to a time series of this length, and when rolling == TRUE the first model will be fit to a series of this length and grow by one each iteration.
maxHorizon	maximum length of the forecast horizon to use for computing errors.
horizonAverage	should the final errors be an average over all forecast horizons up to maxHorizon instead of producing metrics for each individual horizon?
xreg	External regressors to be used to fit the model. Only used if FUN accepts xreg as an argument. FCFUN is also expected to accept it (see details)
saveModels	should the individual models be saved? Set this to FALSE on long time series to save memory.
saveForecasts	should the individual forecast from each model be saved? Set this to FALSE on long time series to save memory.
verbose	should the current progress be printed to the console?
num.cores	the number of cores to use for parallel fitting. If the underlying model that is being fit also utilizes parallelization, the number of cores it is using multiplied by 'num.cores' should not exceed the number of cores available on your machine.
extraPackages	if a custom 'FUN' or 'FCFUN' is being used that requires packages to be loaded, these can be passed here
...	Other arguments to be passed to the model function FUN

## Details

Cross validation of time series data is more complicated than regular k-folds or leave-one-out cross validation of datasets without serial correlation since observations  $x_t$  and  $x_{t+n}$  are not independent. The `cvts()` function overcomes this obstacle using two methods: 1) rolling cross validation where an initial training window is used along with a forecast horizon and the initial window used for training grows by one observation each round until the training window and the forecast horizon capture the entire series or 2) a non-rolling approach where a fixed training length is used that is shifted forward by the forecast horizon after each iteration.

For the rolling approach, training points are heavily recycled, both in terms of used for fitting and in generating forecast errors at each of the forecast horizons from `1:maxHorizon`. In contrast, the models fit with the non-rolling approach share less overlap, and the predicted forecast values are also only compared to the actual values once. The former approach is similar to leave-one-out cross validation while the latter resembles k-fold cross validation. As a result, rolling cross validation requires far more iterations and computationally takes longer to complete, but a disadvantage of the non-rolling approach is the greater variance and general instability of cross-validated errors.

The `FUN` and `FCFUN` arguments specify which function to use for generating a model and forecasting, respectively. While the functions from the "forecast" package can be used, user-defined functions can also be tested, but the object returned by `FCFUN` must accept the argument `h` and contain the point forecasts out to this horizon `h` in slot `$mean` of the returned object. An example is given with a custom model and forecast.

For small time series (default length  $\leq 500$ ), all of the individual fit models are included in the final `cvts` object that is returned. This can grow quite large since functions such as `auto.arima` will save fitted values, residual values, summary statistics, coefficient matrices, etc. Setting `saveModels = FALSE` can be safely done if there is no need to examine individual models fit at every stage of cross validation since the forecasts from each fold and the associated residuals are always saved.

External regressors are allowed via the `xreg` argument. It is assumed that both `FUN` and `FCFUN` accept the `xreg` parameter if `xreg` is not `NULL`. If `FUN` does not accept the `xreg` parameter a warning will be given. No warning is provided if `FCFUN` does not use the `xreg` parameter.

## Author(s)

David Shaub

## See Also

[accuracy.cvts](#)

## Examples

```
series <- subset(AirPassengers, end = 50)
cvmod1 <- cvts(AirPassengers, FUN = stlm,
              windowSize = 25, maxHorizon = 12)
accuracy(cvmod1)

# We can also use custom model functions for modeling/forecasting
stlmClean <- function(x){stlm(tsclean(x))}
series <- subset(austres, end = 38)
cvmodCustom <- cvts(series, FUN = stlmClean, windowSize = 26, maxHorizon = 6)
```

```
accuracy(cvmodCustom)

## Not run:
cvmod2 <- cvts(USAccDeaths, FUN = ets,
              saveModels = FALSE, saveForecasts = FALSE,
              windowSize = 36, maxHorizon = 12)

cvmod3 <- cvts(AirPassengers, FUN = hybridModel,
              FCFUN = forecast, rolling = TRUE, windowSize = 48,
              maxHorizon = 12)

## End(Not run)

# Use the rwf() function from the "forecast" package.
# This function does not have a modeling function and
# instead calculates a forecast on the time series directly
series <- subset(AirPassengers, end = 26)
rwcv <- cvts(series, FCFUN = rwf, windowSize = 24, maxHorizon = 1)
```

---

extractForecasts      *Extract cross validated rolling forecasts*

---

## Description

Obtain cross validated forecasts when rolling cross validation is used. The object is not inspected to see if it was fit using a rolling origin

## Usage

```
extractForecasts(cv, horizon = 1)
```

## Arguments

cv	An object of class cvts
horizon	The forecast horizon from each fold to extract

## Details

Combine the cross validated forecasts fit with a rolling origin. This may be useful to visualize and investigate the cross validated performance of the model

## Value

Forecasts computed via a rolling origin

## Author(s)

Ganesh Krishnan

**Examples**

```
cv <- cvts(AirPassengers, FUN = stlm, FCFUN = forecast,
           rolling = TRUE, windowSize = 134, horizon = 2)

extractForecasts(cv)
```

---

fitted.hybridModel     *Extract Model Fitted Values*

---

**Description**

Extract the model fitted values from the hybridModel object.

**Usage**

```
## S3 method for class 'hybridModel'
fitted(object, individual = FALSE, ...)
```

**Arguments**

object	the input hybridModel.
individual	if TRUE, return the fitted values of the component models instead of the fitted values for the whole ensemble model.
...	other arguments (ignored).

**Value**

The fitted values of the ensemble or individual component models.

**See Also**

[accuracy](#)

---

forecast.hybridModel     *Hybrid forecast*

---

**Description**

Forecast method for hybrid models.

**Usage**

```
## S3 method for class 'hybridModel'
forecast(object, h = ifelse(object$frequency > 1, 2 *
  object$frequency, 10), xreg = NULL, level = c(80, 95), PI = TRUE,
  fan = FALSE, PI.combination = c("extreme", "mean"), ...)
```

**Arguments**

object	a hybrid time series model fit with <a href="#">hybridModel</a> .
h	number of periods for forecasting. If xreg is used, h is ignored and the number of forecast periods is set to the number of rows of xreg.
xreg	future values of regression variables (for use if one of the ensemble methods used in creating the hybrid forecast was <code>auto.arima</code> , <code>nnetar</code> , or <code>stlm</code> and the model(s) used xreg in the fit)
level	confidence level for prediction intervals. This can be expressed as a decimal between 0.0 and 1.0 or numeric between 0 and 100.
PI	should prediction intervals be produced? If a <code>nnetar</code> model is in the ensemble, this can be quite slow, so disabling prediction intervals will speed up the forecast generation. If FALSE, the arguments <code>level</code> and <code>fan</code> are ignored.
fan	if TRUE, level is set to <code>seq(51, 99, by = 3)</code> . This is suitable for fan plots.
PI.combination	Method for combining the prediction intervals from each of the component forecasts. Supplying "mean" will simply average each of the lower/upper intervals from each model without using the model weights used for the point forecasts. The default value "extreme" will take the most pessimistic intervals (i.e. the highest upper interval from all the component models and the lowest prediction interval from all of the component models').
...	other arguments passed to the individual forecast generic methods.

**Details**

if xreg was used in constructing the `hybridModel`, it must also be passed into `forecast.hybridModel`.

While prediction intervals are produced for the final ensemble forecast model, these should be viewed conservatively as insights to the forecast's uncertainty. Currently these are constructed using the most extreme interval from each component model for each horizon, so the composite prediction intervals do not have statistical guarantees of asymptotic efficiency. More sophisticated and rigorous techniques are planned, however, particularly when cross validation approaches are used.

**Value**

An object of class [forecast](#).

**Author(s)**

David Shaub

**See Also**

[hybridModel](#)



**Examples**

```
## Not run:
mod <- hybridModel(AirPassengers)
fc <- forecast(mod)

# View the point forecasts
fc$mean

# View the upper prediction interval
fc$upper

# View the lower prediction interval
fc$lower

# Plot the forecast
plot(fc)

## End(Not run)
```

---

forecast.thetam	<i>Forecast using a Theta model</i>
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---

**Description**

Returns forecasts and other information for univariate Theta "models"

**Usage**

```
## S3 method for class 'thetam'
forecast(object, h = ifelse(object$m > 1, 2 * object$m, 10),
  level = c(80, 95), fan = FALSE, ...)
```

**Arguments**

object	An object of class "thetam. Usually the result of a call to link{thetam}.
h	Number of periods for forecasting
level	Confidence level for prediction intervals
fan	If TRUE, level is set to seq(51, 99, by = 3). This is suitable for fan plots.
...	Ignored

**Value**

An object of class forecast

**Author(s)**

Peter Ellis

**See Also**[thetam](#)**Examples**

```
mod1 <- thetam(Nile)
fc1 <- forecast(mod1)
plot(fc1)
```

---

hybridModel

*Hybrid time series modelling*


---

**Description**

Create a hybrid time series model with two to five component models.

**Usage**

```
hybridModel(y, models = "aefnst", lambda = NULL, a.args = NULL,
  e.args = NULL, n.args = NULL, s.args = NULL, t.args = NULL,
  weights = c("equal", "insample.errors", "cv.errors"),
  errorMethod = c("RMSE", "MAE", "MASE"), cvHorizon = frequency(y),
  windowSize = 84, horizonAverage = FALSE, parallel = FALSE,
  num.cores = 2L, verbose = TRUE)
```

**Arguments**

<code>y</code>	A numeric vector or time series.
<code>models</code>	A character string of up to seven characters indicating which contributing models to use: a ( <a href="#">auto.arima</a> ), e ( <a href="#">ets</a> ), f ( <a href="#">thetam</a> ), n ( <a href="#">nnetar</a> ), s ( <a href="#">stlm</a> ), t ( <a href="#">tbats</a> ), and z ( <a href="#">snaive</a> ).
<code>lambda</code>	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.
<code>a.args</code>	an optional list of arguments to pass to <a href="#">auto.arima</a> . See details.
<code>e.args</code>	an optional list of arguments to pass to <a href="#">ets</a> . See details.
<code>n.args</code>	an optional list of arguments to pass to <a href="#">nnetar</a> . See details.
<code>s.args</code>	an optional list of arguments to pass to <a href="#">stlm</a> . See details.
<code>t.args</code>	an optional list of arguments to pass to <a href="#">tbats</a> . See details.
<code>weights</code>	method for weighting the forecasts of the various contributing models. Defaults to <code>equal</code> , which has shown to be robust and better in many cases than giving more weight to models with better in-sample performance. Cross validated errors—implemented with <code>link{cvts}</code> should produce the best forecast, but the model estimation is also the slowest. Note that extra arguments passed in <code>a.args</code> , <code>e.args</code> , <code>n.args</code> , <code>s.args</code> , and <code>t.args</code> are not used during cross validation. See further explanation in <a href="#">cvts</a> . Weights utilizing in-sample errors are also available but not recommended.

errorMethod	method of measuring accuracy to use if weights are not to be equal. Root mean square error (RMSE), mean absolute error (MAE) and mean absolute scaled error (MASE) are supported.
cvHorizon	If <code>weights = "cv.errors"</code> , this controls which forecast to horizon to use for the error calculations.
windowSize	length of the window to build each model, only used when <code>weights = "cv.errors"</code> .
horizonAverage	If <code>weights = "cv.errors"</code> , setting this to TRUE will average all forecast horizons up to <code>cvHorizon</code> for calculating the errors instead of using the single horizon given in <code>cvHorizon</code> .
parallel	a boolean indicating if parallel processing should be used between models. This is currently unimplemented. Parallelization will still occur within individual models that support it and can be controlled using <code>a.args</code> and <code>t.args</code> .
num.cores	If <code>parallel=TRUE</code> , how many cores to use.
verbose	Should the status of which model is being fit/cross validated be printed to the terminal?

### Details

The `hybridModel` function fits multiple individual model specifications to allow easy creation of ensemble forecasts. While default settings for the individual component models work quite well in most cases, fine control can be exerted by passing detailed arguments to the component models in the `a.args`, `e.args`, `n.args`, `s.args`, and `t.args` lists. Note that if `xreg` is passed to the `a.args`, `n.args`, or `s.args` component models it must be passed as a dataframe instead of the matrix object that the "forecast" package functions usually accept. This is due to a limitation in how the component models are called.

Characteristics of the input series can cause problems for certain types of models and parameters. For example, `stlm` models require that the input series be seasonal; furthermore, the data must include at least two seasons of data (i.e.  $\text{length}(y) \geq 2 * \text{frequency}(y)$ ) for the decomposition to succeed. If this is not the case, `hybridModel()` will remove the `stlm` model so an error does not occur. Similarly, `nnetar` models require that  $\text{length}(y) \geq 2 * \text{frequency}(y)$ , so these models will be removed if the condition is not satisfied. The `ets` model does not handle a series well with a seasonal period longer than 24 and will ignore the seasonality. In this case, `hybridModel()` will also drop the `ets` model from the ensemble.

### Value

An object of class `hybridModel`. The individual component models are stored inside of the object and can be accessed for all the regular manipulations available in the forecast package.

### Author(s)

David Shaub

### See Also

[forecast.hybridModel](#), [auto.arima](#), [ets](#), [thetam](#), [nnetar](#), [stlm](#), [tbats](#)

## Examples

```
## Not run:

# Fit an auto.arima, ets, thetam, nnetar, stlm, and tbats model
# on the time series with equal weights
mod1 <- hybridModel(AirPassengers)
plot(forecast(mod1))

# Use an auto.arima, ets, and tbats model with weights
# set by the MASE in-sample errors
mod2 <- hybridModel(AirPassengers, models = "aet",
weights = "insample.errors", errorMethod = "MASE")

# Pass additional arguments to auto.arima() to control its fit
mod3 <- hybridModel(AirPassengers, models = "aens",
a.args = list(max.p = 7, max.q = 7, approximation = FALSE))

# View the component auto.arima() and stlm() models
mod3$auto.arima
mod3$stlm

## End(Not run)
```

---

is.hybridModel

*Test if the object is a hybridModel object*

---

## Description

Test if the object is a hybridModel object.

## Usage

```
is.hybridModel(x)
```

## Arguments

x                   the input object.

## Value

A boolean indicating if the object is a hybridModel is returned.

---

plot.hybridModel      *Plot a hybridModel object*

---

### Description

Plot a representation of the hybridModel.

### Usage

```
## S3 method for class 'hybridModel'  
plot(x, type = c("fit", "models"), ggplot = FALSE,  
     ...)
```

### Arguments

x	an object of class hybridModel to plot.
type	if type = "fit", plot the original series and the individual fitted models. If type = "models", use the regular plot methods from the component models, i.e. <a href="#">plot.Arima</a> , <a href="#">plot.ets</a> , <a href="#">plot.tbats</a> . Note: no plot methods exist for nnetar and stlm objects, so these will not be plotted with type = "models".
ggplot	should the <a href="#">autoplot</a> function be used (when available) for the plots?
...	other arguments passed to <a href="#">plot</a> .

### Details

For type = "fit", the original series is plotted in black. Fitted values for the individual component models are plotted in other colors. For type = "models", each individual component model is plotted. Since there is not plot method for stlm or nnetar objects, these component models are not plotted.

### Value

None. Function produces a plot.

### Author(s)

David Shaub

### See Also

[hybridModel](#)

**Examples**

```
## Not run:
hm <- hybridModel(woolyrnq, models = "aenst")
plot(hm, type = "fit")
plot(hm, type = "models")

## End(Not run)
```

---

plot.thetam

*Plot components from Theta model*

---

**Description**

Produces a plot of the level components from the ETS model underlying a Theta model

**Usage**

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

**Arguments**

x                    Object of class "thetam".  
...                   Other plotting parameters passed through to plot

**Details**

The "state" component of the plot comes from the model `ets(..., model = "ANN")` that was fit as part of the theta method. The "seasonal" component is the multipliers from multiplicative classical decomposition seasonal adjustment that is performed before the ets model is fit. The "linear" component shows the direction and slope of drift that is used in the forecasting to come.

**Value**

None. Function produces a plot.

**Author(s)**

Peter Ellis

**See Also**

[thetam](#)

**Examples**

```
model <- thetam(wineind)
plot(model)
```

---

print.hybridModel      *Print information about the hybridModel object*

---

**Description**

Print information about the hybridModel object.

**Usage**

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

**Arguments**

x                    the input hybridModel object.  
...                   other arguments (ignored).

**Details**

Print the names of the individual component models and their weights.

---

residuals.hybridModel    *Extract Model Residuals*

---

**Description**

Extract the model residuals from the hybridModel object.

**Usage**

```
## S3 method for class 'hybridModel'  
residuals(object, individual = FALSE, ...)
```

**Arguments**

object                The input hybridModel.  
individual            If TRUE, return the residuals of the component models instead of the residuals for the whole ensemble model.  
...                    Other arguments (ignored).

**Value**

The residuals of the ensemble or individual component models.

**See Also**

[accuracy](#)

---

```
summary.hybridModel Print a summary of the hybridModel object
```

---

**Description**

Print a summary of the hybridModel object

**Usage**

```
## S3 method for class 'hybridModel'
summary(x)
```

**Arguments**

x                    the input hybridModel object.

**Details**

Print the names of the individual component models and their weights.

---

```
thetam                    Theta method 'model'
```

---

**Description**

Create a model object as an interim step to a theta method forecast.

**Usage**

```
thetam(y)
```

**Arguments**

y                    A numeric vector or time series.

**Details**

This fits an exponential smoothing state space model with `model = 'ANN'` to `y`, having first performed classic multiplicative seasonal adjustment. A drift value is also calculated by `lsfit(0:(length(y) - 1), y)$coef[1]`. In combination with `forecast.thetam()`, this provides identical results to `forecast::thetaf(...)`. The purpose of splitting it into a 'model' and 'forecast' functions is to make the approach consistent with other modelling / forecasting approaches used in `hybridModel()`.

**Value**

An object of class `thetam`



**Author(s)**

Peter Ellis

**See Also**[forecast.thetam](#)**Examples**

```
mod1 <- thetam(Nile)
plot(mod1)
```

---

`tsCombine`*Combine multiple sequential time series*

---

**Description**

Combine multiple ts objects into a single ts object. It is assumed that the ts objects provided are sequential. In other words, it is assumed that a valid time series object can actually be constructed from the provided objects. The start time and frequency of the combined object will correspond to the start time and frequency of the first provided object

**Usage**

```
tsCombine(...)
```

**Arguments**

```
...          ts objects to combine
```

**Details**

Combine sequential time series objects into a single time series object. This might be useful, for example, when you want to combine the training and validation time series objects for plotting. The function assumes that the provided objects have no overlap. For example, a valid argument set would have two time series with periods from Jan-Dec 2015 and Jan-Dec 2016. An invalid set would be two time series t1 and t2 with periods from Jan-Dec 2015 and Aug 2015-Dec 2016 respectively. In that case, there is overlap between t1 and t2. The return value will depend on the order in which the arguments are provided. If the function call is `tsCombine(t1, t2)`, the overlapping portion of t1 and t2 (Aug-Dec 2015 in this example), would have values from t1 as long as they are not NA. If the call is `tsCombine(t2, t1)`, it will have values from t2 as long as they are not NA.

**Value**

A combined ts object generated from the individual ts objects

**Author(s)**

Ganesh Krishnan

**Examples**

```
tsCombine(window(AirPassengers, end = c(1951, 12)), window(AirPassengers, start = c(1952, 1)))
```

---

`tsPartition`*Generate training and test indices for time series cross validation*

---

**Description**

Training and test indices are generated for time series cross validation. Generated indices are based on the training windowSize, forecast horizons and whether a rolling or non-rolling cross validation procedure is desired.

**Usage**

```
tsPartition(x, rolling, windowSize, maxHorizon)
```

**Arguments**

x	A time series
rolling	Should indices be generated for a rolling or non-rolling procedure?
windowSize	Size of window for training
maxHorizon	Maximum forecast horizon

**Value**

List containing train and test indices for each fold

**Author(s)**

Ganesh Krishnan

**Examples**

```
tsPartition(AirPassengers, rolling = TRUE, windowSize = 10, maxHorizon = 2)
```

---

tsSubsetWithIndices    *Subset time series with provided indices*

---

**Description**

Use provided indices to subset a time series. The provided indices must be contiguous

**Usage**

```
tsSubsetWithIndices(x, indices)
```

**Arguments**

x	A time series object
indices	A contiguous vector of indices to use for subsetting

**Value**

A time series object appropriately subsetted using provided indices

**Author(s)**

Ganesh Krishnan

**Examples**

```
tsSubsetWithIndices(AirPassengers, c(3:10))
```

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