Package ‘forecast’

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Version 8.0

Title Forecasting Functions for Time Series and Linear Models

Description Methods and tools for displaying and analysing
univariate time series forecasts including exponential smoothing
via state space models and automatic ARIMA modelling.

Depends R (>= 3.0.2),

Imports stats, graphics, tseries, fracdiff, Rcpp (>= 0.11.0), nnet,
colorspace, parallel, ggplot2 (>= 2.0.0), magrittr, lmtest,
zoo, timeDate

Suggests testthat, knitr, rmarkdown, expsmooth, rticles

LinkingTo Rcpp (>= 0.11.0), RcppArmadillo (>= 0.2.35)

LazyData yes

ByteCompile TRUE

BugReports https://github.com/robjhyndman/forecast/issues

License GPL (>= 2)

URL http://github.com/robjhyndman/forecast

VignetteBuilder knitr

NeedsCompilation yes

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R topics documented:

`accuracy` *Accuracy measures for forecast model*

Description

Returns range of summary measures of the forecast accuracy. If `x` is provided, the function measures out-of-sample (test set) forecast accuracy based on x-f. If `x` is not provided, the function only produces in-sample (training set) accuracy measures of the forecasts based on f["x"]-fitted(f). All measures are defined and discussed in Hyndman and Koehler (2006).

Usage

```
accuracy(f, x, test=NULL, d=NULL, D=NULL)
```

Arguments

`f`	An object of class `"forecast"`, or a numerical vector containing forecasts. It will also work with `Arima`, `ets` and `lm` objects if `x` is omitted – in which case in-sample accuracy measures are returned.
`x`	An optional numerical vector containing actual values of the same length as object, or a time series overlapping with the times of `f`.
`test`	Indicator of which elements of x and f to test. If `test` is `NULL`, all elements are used. Otherwise test is a numeric vector containing the indices of the elements to use in the test.
`d`	An integer indicating the number of lag-1 differences to be used for the denominator in MASE calculation. Default value is 1 for non-seasonal series and 0 for seasonal series.
`D`	An integer indicating the number of seasonal differences to be used for the denominator in MASE calculation. Default value is 0 for non-seasonal series and 1 for seasonal series.

Details

The measures calculated are:

- ME: Mean Error
- RMSE: Root Mean Squared Error
- MAE: Mean Absolute Error
- MPE: Mean Percentage Error
- MAPE: Mean Absolute Percentage Error
- MASE: Mean Absolute Scaled Error
- ACF1: Autocorrelation of errors at lag 1.

By default, the MASE calculation is scaled using MAE of in-sample naive forecasts for non-seasonal time series, in-sample seasonal naive forecasts for seasonal time series and in-sample mean forecasts for non-time series data.

See Hyndman and Koehler (2006) and Hyndman and Athanasopoulos (2014, Section 2.5) for further details.

Value

Matrix giving forecast accuracy measures.

Author(s)

Rob J Hyndman

References

Hyndman, R.J. and Koehler, A.B. (2006) "Another look at measures of forecast accuracy". *International Journal of Forecasting*, **22**(4), 679-688. Hyndman, R.J. and Athanasopoulos, G. (2014) "Forecasting: principles and practice", OTexts. Section 2.5 "Evaluating forecast accuracy". http://www.otexts.org/fpp/2/5.

Examples

```
fit1 <- rwf(EuStockMarkets[1:200,1],h=100)
fit2 <- meanf(EuStockMarkets[1:200,1],h=100)
accuracy(fit1)
accuracy(fit2)
accuracy(fit1,EuStockMarkets[201:300,1])
accuracy(fit2,EuStockMarkets[201:300,1])
plot(fit1)
lines(EuStockMarkets[1:300,1])
```

Acf *(Partial) Autocorrelation and Cross-Correlation Function Estimation*

Description

The function `Acf` computes (and by default plots) an estimate of the autocorrelation function of a (possibly multivariate) time series. Function `Pacf` computes (and by default plots) an estimate of the partial autocorrelation function of a (possibly multivariate) time series. Function `Ccf` computes the cross-correlation or cross-covariance of two univariate series.

Usage

```
Acf(x, lag.max = NULL,
  type = c("correlation", "covariance", "partial"),
  plot = TRUE, na.action = na.contiguous, demean=TRUE, ...)
Pacf(x, lag.max=NULL,
  plot = TRUE, na.action = na.contiguous, demean=TRUE, ...)
Ccf(x, y, lag.max=NULL, type=c("correlation","covariance"),
  plot=TRUE, na.action=na.contiguous, ...)
taperedacf(x, lag.max=NULL, type=c("correlation", "partial"),
  plot=TRUE, calc.ci=TRUE, level=95, nsim=100, ...)
taperedpacf(x, ...)
```

Arguments

`x`	a univariate or multivariate (not Ccf) numeric time series object or a numeric vector or matrix.
`y`	a univariate numeric time series object or a numeric vector.
`lag.max`	maximum lag at which to calculate the acf. Default is $10*log10(N/m)$ where N is the number of observations and m the number of series. Will be automatically limited to one less than the number of observations in the series.
`type`	character string giving the type of acf to be computed. Allowed values are `"correlation"` (the default), `"covariance"` or `"partial"`.
`plot`	logical. If `TRUE` (the default) the resulting acf, pacf or ccf is plotted.
`na.action`	function to handle missing values. Default is `na.contiguous`. Useful alternatives are `na.pass` and `na.interp`.
`demean`	Should covariances be about the sample means?
`calc.ci`	If `TRUE`, confidence intervals for the ACF/PACF estimates are calculated.
`level`	Percentage level used for the confidence intervals.
`nsim`	The number of bootstrap samples used in estimating the confidence intervals.
`...`	Additional arguments passed to the plotting function.

Details

The functions improve the `acf`, `pacf` and `ccf` functions. The main differences are that `Acf` does not plot a spike at lag 0 when `type=="correlation"` (which is redundant) and the horizontal axes show lags in time units rather than seasonal units.

The tapered versions implement the ACF and PACF estimates and plots described in Hyndman (2015), based on the banded and tapered estimates of autocovariance proposed by McMurry and Politis (2010).

Value

The `Acf`, `Pacf` and `Ccf` functions return objects of class "acf" as described in `acf` from the stats package. The `taperedacf` and `taperedpacf` functions return objects of class "mpacf".

Author(s)

Rob J Hyndman

References

Hyndman, R.J. (2015). Discussion of “High-dimensional autocovariance matrices and optimal linear prediction”. *Electronic Journal of Statistics*, 9, 792-796.

McMurry, T. L., & Politis, D. N. (2010). Banded and tapered estimates for autocovariance matrices and the linear process bootstrap. *Journal of Time Series Analysis*, 31(6), 471-482.

See Also

`acf`, `pacf`, `ccf`, `tsdisplay`

Examples

```
Acf(wineind)
Pacf(wineind)
## Not run:
taperedacf(wineind, nsim=50)
taperedpacf(wineind, nsim=50)

## End(Not run)
```

---

arfima *Fit a fractionally differenced ARFIMA model*

Description

An ARFIMA(p,d,q) model is selected and estimated automatically using the Hyndman-Khandakar (2008) algorithm to select p and q and the Haslett and Raftery (1989) algorithm to estimate the parameters including d.

Usage

```
arfima(y, drange=c(0, 0.5), estim=c("mle","ls"),
       model=NULL, lambda=NULL, biasadj=FALSE, x=y, ...)
```

Arguments

`y`	a univariate time series (numeric vector).
`drange`	Allowable values of d to be considered. Default of `c(0,0.5)` ensures a stationary model is returned.
`estim`	If `estim=="ls"`, then the ARMA parameters are calculated using the Haslett-Raftery algorithm. If `estim=="mle"`, then the ARMA parameters are calculated using full MLE via the `arima` function.
`model`	Output from a previous call to `arfima`. If model is passed, this same model is fitted to y without re-estimating any parameters.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`x`	Deprecated. Included for backwards compatibility.
`...`	Other arguments passed to `auto.arima` when selecting p and q.

Details

This function combines `fracdiff` and `auto.arima` to automatically select and estimate an ARFIMA model. The fractional differencing parameter is chosen first assuming an ARFIMA(2,d,0) model. Then the data are fractionally differenced using the estimated d and an ARMA model is selected for the resulting time series using `auto.arima`. Finally, the full ARFIMA(p,d,q) model is re-estimated using `fracdiff`. If `estim=="mle"`, the ARMA coefficients are refined using `arima`.

Value

A list object of S3 class `"fracdiff"`, which is described in the `fracdiff` documentation. A few additional objects are added to the list including `x` (the original time series), and the `residuals` and `fitted` values.

Author(s)

Rob J Hyndman and Farah Yasmeen

References

J. Haslett and A. E. Raftery (1989) Space-time Modelling with Long-memory Dependence: Assessing Ireland's Wind Power Resource (with discussion); *Applied Statistics* **38**, 1-50.

Hyndman, R.J. and Khandakar, Y. (2008) "Automatic time series forecasting: The forecast package for R", *Journal of Statistical Software*, **26**(3).

See Also

`fracdiff`, `auto.arima`, `forecast.fracdiff`.

Examples

```
library(fracdiff)
x <- fracdiff.sim( 100, ma=-.4, d=.3)$series
fit <- arfima(x)
tsdisplay(residuals(fit))
```

`Arima` *Fit ARIMA model to univariate time series*

Description

Largely a wrapper for the `arima` function in the stats package. The main difference is that this function allows a drift term. It is also possible to take an ARIMA model from a previous call to `Arima` and re-apply it to the data `y`.

Usage

```
Arima(y, order=c(0,0,0), seasonal=c(0,0,0),
    xreg=NULL, include.mean=TRUE, include.drift=FALSE,
    include.constant, lambda=model$lambda, biasadj=FALSE,
    method=c("CSS-ML","ML","CSS"), model=NULL, x=y,...)
```

Arguments

`y`	a univariate time series of class `ts`.
`order`	A specification of the non-seasonal part of the ARIMA model: the three components (p, d, q) are the AR order, the degree of differencing, and the MA order.
`seasonal`	A specification of the seasonal part of the ARIMA model, plus the period (which defaults to frequency(y)). This should be a list with components order and period, but a specification of just a numeric vector of length 3 will be turned into a suitable list with the specification as the order.
`xreg`	Optionally, a vector or matrix of external regressors, which must have the same number of rows as y.
`include.mean`	Should the ARIMA model include a mean term? The default is TRUE for undifferenced series, FALSE for differenced ones (where a mean would not affect the fit nor predictions).
`include.drift`	Should the ARIMA model include a linear drift term? (i.e., a linear regression with ARIMA errors is fitted.) The default is FALSE.
`include.constant`	If TRUE, then `include.mean` is set to be TRUE for undifferenced series and `include.drift` is set to be TRUE for differenced series. Note that if there is more than one difference taken, no constant is included regardless of the value of this argument. This is deliberate as otherwise quadratic and higher order polynomial trends would be induced.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`method`	Fitting method: maximum likelihood or minimize conditional sum-of-squares. The default (unless there are missing values) is to use conditional-sum-of-squares to find starting values, then maximum likelihood.
`model`	Output from a previous call to `Arima`. If model is passed, this same model is fitted to `y` without re-estimating any parameters.
`x`	Deprecated. Included for backwards compatibility.
`...`	Additional arguments to be passed to `arima`.

Details

See the `arima` function in the stats package.

Value

See the arima function in the stats package. The additional objects returned are

x	The time series data
xreg	The regressors used in fitting (when relevant).

Author(s)

Rob J Hyndman

See Also

auto.arima, forecast.Arima.

Examples

```
fit <- Arima(WWWusage,order=c(3,1,0))
plot(forecast(fit,h=20))

# Fit model to first few years of AirPassengers data
air.model <- Arima(window(AirPassengers,end=1956+11/12),order=c(0,1,1),
                   seasonal=list(order=c(0,1,1),period=12),lambda=0)
plot(forecast(air.model,h=48))
lines(AirPassengers)

# Apply fitted model to later data
air.model2 <- Arima(window(AirPassengers,start=1957),model=air.model)

# Forecast accuracy measures on the log scale.
# in-sample one-step forecasts.
accuracy(air.model)
# out-of-sample one-step forecasts.
accuracy(air.model2)
# out-of-sample multi-step forecasts
accuracy(forecast(air.model,h=48,lambda=NULL),
         log(window(AirPassengers,start=1957)))
```

---

arimaorder *Return the order of an ARIMA or ARFIMA model*

Description

Returns the order of a univariate ARIMA or ARFIMA model.

Usage

```
arimaorder(object)
```

Arguments

`object` An object of class "Arima", "ar" or "fracdiff". Usually the result of a call to `arima`, `Arima`, `auto.arima`, `ar`, `arfima` or `fracdiff`.

Value

A numerical vector giving the values p, d and q of the ARIMA or ARFIMA model. For a seasonal ARIMA model, the returned vector contains the values p, d, q, P, D, Q and m, where m is the period of seasonality.

Author(s)

Rob J Hyndman

See Also

`ar`, `auto.arima`, `Arima`, `arima`, `arfima`.

Examples

```
arimaorder(auto.arima(WWWusage))
```

---

auto.arima *Fit best ARIMA model to univariate time series*

Description

Returns best ARIMA model according to either AIC, AICc or BIC value. The function conducts a search over possible model within the order constraints provided.

Usage

```
auto.arima(y, d=NA, D=NA, max.p=5, max.q=5,
     max.P=2, max.Q=2, max.order=5, max.d=2, max.D=1,
     start.p=2, start.q=2, start.P=1, start.Q=1,
     stationary=FALSE, seasonal=TRUE,
     ic=c("aicc", "aic", "bic"), stepwise=TRUE, trace=FALSE,
     approximation=(length(x)>100 | frequency(x)>12),
     truncate=NULL, xreg=NULL,
     test=c("kpss","adf","pp"), seasonal.test=c("ocsb","ch"),
     allowdrift=TRUE, allowmean=TRUE, lambda=NULL, biasadj=FALSE,
     parallel=FALSE, num.cores=2, x=y, ...)
```

Arguments

y	a univariate time series
d	Order of first-differencing. If missing, will choose a value based on KPSS test.
D	Order of seasonal-differencing. If missing, will choose a value based on OCSB test.
max.p	Maximum value of p
max.q	Maximum value of q
max.P	Maximum value of P
max.Q	Maximum value of Q
max.order	Maximum value of p+q+P+Q if model selection is not stepwise.
max.d	Maximum number of non-seasonal differences
max.D	Maximum number of seasonal differences
start.p	Starting value of p in stepwise procedure.
start.q	Starting value of q in stepwise procedure.
start.P	Starting value of P in stepwise procedure.
start.Q	Starting value of Q in stepwise procedure.
stationary	If `TRUE`, restricts search to stationary models.
seasonal	If `FALSE`, restricts search to non-seasonal models.
ic	Information criterion to be used in model selection.
stepwise	If `TRUE`, will do stepwise selection (faster). Otherwise, it searches over all models. Non-stepwise selection can be very slow, especially for seasonal models.
trace	If `TRUE`, the list of ARIMA models considered will be reported.
approximation	If `TRUE`, estimation is via conditional sums of squares andthe information criteria used for model selection are approximated. The final model is still computed using maximum likelihood estimation. Approximation should be used for long time series or a high seasonal period to avoid excessive computation times.
truncate	An integer value indicating how many observations to use in model selection. The last `truncate` values of the series are used to select a model when `truncate` is not `NULL` and `approximation=TRUE`. All observations are used if either `truncate=NULL` or `approximation=FALSE`.
xreg	Optionally, a vector or matrix of external regressors, which must have the same number of rows as `y`.
test	Type of unit root test to use. See `ndiffs` for details.
seasonal.test	This determines which seasonal unit root test is used. See `nsdiffs` for details.
allowdrift	If `TRUE`, models with drift terms are considered.
allowmean	If `TRUE`, models with a non-zero mean are considered.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.

`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`parallel`	If `TRUE` and `stepwise = FALSE`, then the specification search is done in parallel. This can give a significant speedup on mutlicore machines.
`num.cores`	Allows the user to specify the amount of parallel processes to be used if `parallel = TRUE` and `stepwise = FALSE`. If `NULL`, then the number of logical cores is automatically detected and all available cores are used.
`x`	Deprecated. Included for backwards compatibility.
`...`	Additional arguments to be passed to `arima`.

Details

Non-stepwise selection can be slow, especially for seasonal data. Stepwise algorithm outlined in Hyndman and Khandakar (2008) except that the default method for selecting seasonal differences is now the OCSB test rather than the Canova-Hansen test.

Value

Same as for `Arima`

Author(s)

Rob J Hyndman

References

Hyndman, R.J. and Khandakar, Y. (2008) "Automatic time series forecasting: The forecast package for R", *Journal of Statistical Software*, **26**(3).

See Also

`Arima`

Examples

```
fit <- auto.arima(WWWusage)
plot(forecast(fit,h=20))
```

autolayer *Create a ggplot layer appropriate to a particular data type*

Description

`autolayer` uses ggplot2 to draw a particular layer for an object of a particular class in a single command. This defines the S3 generic that other classes and packages can extend.

Usage

```
autolayer(object, ...)
```

Arguments

`object`	an object, whose class will determine the behaviour of autoplot
`...`	other arguments passed to specific methods

Value

a ggplot layer

See Also

`autoplot`, `ggplot`, `fortify`

autoplot.acf *ggplot (Partial) Autocorrelation and Cross-Correlation Function Estimation*

Description

Produces a ggplot object of their equivelent Acf, Pacf, Ccf, taperedacf and taperedpacf functions.

If `autoplot` is given an `acf` or `mpacf` function, then an appropriate ggplot object will be created.

Usage

```
## S3 method for class 'acf'
autoplot(object, ci=0.95, ...)
## S3 method for class 'mpacf'
autoplot(object, ...)

ggAcf(x, lag.max = NULL,
    type = c("correlation", "covariance", "partial"),
    plot = TRUE, na.action = na.contiguous, demean=TRUE, ...)
ggPacf(x, lag.max = NULL,
```

```
    plot = TRUE, na.action = na.contiguous, demean=TRUE, ...)
ggCcf(x, y, lag.max=NULL, type=c("correlation","covariance"),
    plot=TRUE, na.action=na.contiguous, ...)
ggtaperedacf(x, lag.max=NULL, type=c("correlation", "partial"),
   plot=TRUE, calc.ci=TRUE, level=95, nsim=100, ...)
ggtaperedpacf(x, ...)
```

Arguments

`object`	Object of class “acf”.
`x`	a univariate or multivariate (not Ccf) numeric time series object or a numeric vector or matrix.
`y`	a univariate numeric time series object or a numeric vector.
`ci`	coverage probability for confidence interval. Plotting of the confidence interval is suppressed if ci is zero or negative.
`lag.max`	maximum lag at which to calculate the acf.
`type`	character string giving the type of acf to be computed. Allowed values are `"correlation"` (the default), `"covariance"` or `"partial"`.
`plot`	logical. If `TRUE` (the default) the resulting acf, pacf or ccf is plotted.
`na.action`	function to handle missing values. Default is `na.contiguous`. Useful alternatives are `na.pass` and `na.interp`.
`demean`	Should covariances be about the sample means?
`calc.ci`	If `TRUE`, confidence intervals for the ACF/PACF estimates are calculated.
`level`	Percentage level used for the confidence intervals.
`nsim`	The number of bootstrap samples used in estimating the confidence intervals.
`...`	Other plotting parameters to affect the plot.

Value

None. Function produces a ggplot graph.

Author(s)

Mitchell O'Hara-Wild

See Also

`plot.acf`, `Acf`, `acf`, `taperedacf`

Examples

```
library(ggplot2)
ggAcf(wineind)
wineind %>% Acf(plot=FALSE) %>% autoplot
## Not run:
wineind %>% taperedacf(plot=FALSE) %>% autoplot
```

```
ggtaperedacf(wineind)
ggtaperedpacf(wineind)
## End(Not run)
ggCcf(mdeaths, fdeaths)
```

autoplot.seas — *Plot time series decomposition components using ggplot*

Description

Produces a ggplot object of seasonally decomposed time series for objects of class "stl" (created with `stl`), class "seas" (created with `seas`), or class "decomposed.ts" (created with `decompose`).

Usage

```
## S3 method for class 'seas'
autoplot(object, labels = NULL, range.bars = NULL, ...)
## S3 method for class 'stl'
autoplot(object, labels = NULL, range.bars = TRUE, ...)
## S3 method for class 'decomposed.ts'
autoplot(object, labels = NULL, range.bars = NULL, ...)
## S3 method for class 'StructTS'
autoplot(object, labels = NULL, range.bars = TRUE, ...)
```

Arguments

`object`	Object of class “seas”, “stl”, or “decomposed.ts”.
`labels`	Labels to replace "seasonal", "trend", and "remainder".
`range.bars`	Logical indicating if each plot should have a bar at its right side representing relative size. If NULL, automatic selection takes place.
`...`	Other plotting parameters to affect the plot.

Value

Returns an object of class `ggplot`.

Author(s)

Mitchell O’Hara-Wild

See Also

`seas`, `stl`, `decompose`, `StructTS`, `plot.stl`.

Examples

```
library(ggplot2)
co2 %>% decompose %>% autoplot
nottem %>% stl(s.window='periodic') %>% autoplot

## Not run:
library(seasonal)
m <- seas(USAccDeaths)
autoplot(m)

## End(Not run)
```

`autoplot.ts` *Automatically create a ggplot for time series objects*

Description

`autoplot` takes an object of type `ts` or `mts` and creates a ggplot object suitable for usage with `stat_forecast`.

`fortify.ts` takes a `ts` object and converts it into a data frame (for usage with ggplot2).

Usage

```
## S3 method for class 'ts'
autoplot(object, series = NULL, ...)
## S3 method for class 'mts'
autoplot(object, colour=TRUE, facets=FALSE, ...)
## S3 method for class 'ts'
autolayer(object, colour=TRUE, series=NULL, ...)
## S3 method for class 'mts'
autolayer(object, colour=TRUE, series=NULL, ...)
## S3 method for class 'ts'
fortify(model,data, ...)
```

Arguments

`object`	Object of class "ts" or "mts".
`series`	Identifies the timeseries with a colour, which integrates well with the functionality of geom_forecast.
`facets`	If TRUE, multiple time series will be faceted (and unless specified, colour is set to FALSE). If FALSE, each series will be assigned a colour.
`colour`	If TRUE, the time series will be assigned a colour aesthetic
`model`	Object of class "ts" to be converted to "data.frame".
`data`	Not used (required for fortify method)
`...`	Other plotting parameters to affect the plot.

Value

None. Function produces a ggplot graph.

Author(s)

Mitchell O'Hara-Wild

See Also

plot.ts, fortify

Examples

```
library(ggplot2)
autoplot(USAccDeaths)

lungDeaths <- cbind(mdeaths, fdeaths)
autoplot(lungDeaths)
autoplot(lungDeaths, facets=TRUE)
```

---

baggedETS *Forecasting using the bagged ETS method*

Description

The bagged ETS forecasting method.

Usage

```
baggedETS(y, bootstrapped_series=bld.mbb.bootstrap(y, 100), ...)
```

Arguments

y	A numeric vector or time series.
bootstrapped_series	bootstrapped versions of y.
...	Other arguments passed to ets.

Details

This function implements the bagged ETS forecasting method described in Bergmeir et al. The ets function is applied to all bootstrapped series. Using the default parameters, the function bld.mbb.bootstrap is used to calculate the bootstrapped series with the Box-Cox and Loess-based decomposition (BLD) bootstrap. The function forecast.baggedETS can then be used to calculate forecasts.

Value

Returns an object of class "baggedETS".

The function `print` is used to obtain and print a summary of the results.

`models`	A list containing the fitted ETS ensemble models.
`method`	The name of the forecasting method as a character string
`y`	The original time series.
`bootstrapped_series`	The bootstrapped series.
`etsargs`	The arguments passed through to `ets`.
`fitted`	Fitted values (one-step forecasts). The mean is of the fitted values is calculated over the ensemble.
`residuals`	Original values minus fitted values.

Author(s)

Christoph Bergmeir, Fotios Petropoulos

References

Bergmeir, C., R. J. Hyndman, and J. M. Benitez (2016). Bagging Exponential Smoothing Methods using STL Decomposition and Box-Cox Transformation. International Journal of Forecasting 32, 303-312.

Examples

```
fit <- baggedETS(WWWusage)
fcast <- forecast(fit)
plot(fcast)
```

---

bats — *BATS model (Exponential smoothing state space model with Box-Cox transformation, ARMA errors, Trend and Seasonal components)*

Description

Fits a BATS model applied to `y`, as described in De Livera, Hyndman & Snyder (2011). Parallel processing is used by default to speed up the computations.

Usage

```
bats(y, use.box.cox=NULL, use.trend=NULL, use.damped.trend=NULL,
  seasonal.periods=NULL, use.arma.errors=TRUE, use.parallel=length(y)>1000,
  num.cores=2, bc.lower=0, bc.upper=1, biasadj=FALSE, model=NULL, ...)
```

Arguments

- `y` — The time series to be forecast. Can be `numeric`, `msts` or `ts`. Only univariate time series are supported.
- `use.box.cox` — `TRUE/FALSE` indicates whether to use the Box-Cox transformation or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `use.trend` — `TRUE/FALSE` indicates whether to include a trend or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `use.damped.trend` — `TRUE/FALSE` indicates whether to include a damping parameter in the trend or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `seasonal.periods` — If `y` is a numeric then seasonal periods can be specified with this parameter.
- `use.arma.errors` — `TRUE/FALSE` indicates whether to include ARMA errors or not. If `TRUE` the best fit is selected by AIC. If `FALSE` then the selection algorithm does not consider ARMA errors.
- `use.parallel` — `TRUE/FALSE` indicates whether or not to use parallel processing.
- `num.cores` — The number of parallel processes to be used if using parallel processing. If `NULL` then the number of logical cores is detected and all available cores are used.
- `bc.lower` — The lower limit (inclusive) for the Box-Cox transformation.
- `bc.upper` — The upper limit (inclusive) for the Box-Cox transformation.
- `biasadj` — Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
- `model` — Output from a previous call to `bats`. If model is passed, this same model is fitted to `y` without re-estimating any parameters.
- `...` — Additional arguments to be passed to `auto.arima` when choose an ARMA(p, q) model for the errors. (Note that xreg will be ignored, as will any arguments concerning seasonality and differencing, but arguments controlling the values of p and q will be used.)

Value

An object of class "`bats`". The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `bats` and associated functions. The fitted model is designated BATS(omega, p,q, phi, m1,...mJ) where omega is the Box-Cox parameter and phi is the damping parameter; the error is modelled as an ARMA(p,q) process and m1,...,mJ list the seasonal periods used in the model.

Author(s)

Slava Razbash and Rob J Hyndman

References

De Livera, A.M., Hyndman, R.J., & Snyder, R. D. (2011), Forecasting time series with complex seasonal patterns using exponential smoothing, *Journal of the American Statistical Association*, **106**(496), 1513-1527.

Examples

```
## Not run:
fit <- bats(USAccDeaths)
plot(forecast(fit))

taylor.fit <- bats(taylor)
plot(forecast(taylor.fit))
## End(Not run)
```

---

bizdays *Number of trading days in each season*

Description

Returns number of trading days in each month or quarter of the observed time period in a major financial center.

Usage

```
bizdays(x, FinCenter = c("New York", "London", "NERC", "Tokyo", "Zurich"))
```

Arguments

`x`	Monthly or quarterly time series
`FinCenter`	Major financial center.

Details

Useful for trading days length adjustments. More on how to define "business days", please refer to `isBizday`.

Value

Time series

Author(s)

Earo Wang

See Also

`monthdays`

Examples

```
x <-  ts(rnorm(30), start = c(2013, 2), frequency = 12)
bizdays(x, FinCenter = "New York")
```

---

bld.mbb.bootstrap — *Box-Cox and Loess-based decomposition bootstrap.*

Description

Generates bootstrapped versions of a time series using the Box-Cox and Loess-based decomposition bootstrap.

Usage

```
bld.mbb.bootstrap(x, num,
    block_size = if(frequency(x)>1) 2*frequency(x) else 8 )
```

Arguments

`x`	Original time series.
`num`	Number of bootstrapped versions to generate.
`block_size`	Block size for the moving block bootstrap.

Details

The procedure is described in Bergmeir et al. Box-Cox decomposition is applied, together with STL or Loess (for non-seasonal time series), and the remainder is bootstrapped using a moving block bootstrap.

Value

A list with bootstrapped versions of the series. The first series in the list is the original series.

Author(s)

Christoph Bergmeir, Fotios Petropoulos

References

Bergmeir, C., R. J. Hyndman, and J. M. Benitez (2016). Bagging Exponential Smoothing Methods using STL Decomposition and Box-Cox Transformation. International Journal of Forecasting 32, 303-312.

See Also

baggedETS.

Examples

```
bootstrapped_series <- bld.mbb.bootstrap(WWWusage, 100)
```

BoxCox *Box Cox Transformation*

Description

BoxCox() returns a transformation of the input variable using a Box-Cox transformation. InvBoxCox() reverses the transformation.

Usage

```
BoxCox(x, lambda)
InvBoxCox(x, lambda, biasadj=FALSE, fvar=NULL)
```

Arguments

`x`	a numeric vector or time series
`lambda`	transformation parameter
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`fvar`	Optional parameter required if biasadj=TRUE. Can either be the forecast variance, or a list containing the interval `level`, and the corresponding `upper` and `lower` intervals.

Details

The Box-Cox transformation is given by

$$f_\lambda(x) = \frac{x^\lambda - 1}{\lambda}$$

if $\lambda \neq 0$. For $\lambda = 0$,

$$f_0(x) = \log(x)$$

.

Value

a numeric vector of the same length as x.

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

References

Box, G. E. P. and Cox, D. R. (1964) An analysis of transformations. *JRSS B* **26** 211–246.

See Also

BoxCox.lambda

Examples

```
lambda <- BoxCox.lambda(lynx)
lynx.fit <- ar(BoxCox(lynx,lambda))
plot(forecast(lynx.fit,h=20,lambda=lambda))
```

BoxCox.lambda — *Automatic selection of Box Cox transformation parameter*

Description

If `method=="guerrero"`, Guerrero's (1993) method is used, where lambda minimizes the coefficient of variation for subseries of `x`.

If `method=="loglik"`, the value of lambda is chosen to maximize the profile log likelihood of a linear model fitted to `x`. For non-seasonal data, a linear time trend is fitted while for seasonal data, a linear time trend with seasonal dummy variables is used.

Usage

```
BoxCox.lambda(x, method=c("guerrero","loglik"), lower=-1, upper=2)
```

Arguments

`x`	a numeric vector or time series
`method`	Choose method to be used in calculating lambda.
`lower`	Lower limit for possible lambda values.
`upper`	Upper limit for possible lambda values.

Value

a number indicating the Box-Cox transformation parameter.

Author(s)

Leanne Chhay and Rob J Hyndman

References

Box, G. E. P. and Cox, D. R. (1964) An analysis of transformations. *JRSS B* **26** 211–246.

Guerrero, V.M. (1993) Time-series analysis supported by power transformations. *Journal of Forecasting*, **12**, 37–48.

See Also

`BoxCox`

Examples

```
lambda <- BoxCox.lambda(AirPassengers,lower=0)
air.fit <- Arima(AirPassengers, order=c(0,1,1),
                 seasonal=list(order=c(0,1,1),period=12), lambda=lambda)
plot(forecast(air.fit))
```

`checkresiduals` *Check that residuals from a time series model look like white noise*

Description

Produces a time plot of the residuals, the corresponding ACF, and a histogram. If the degrees of freedom for the model can be determined, the output from either a Breusch-Godfrey test or a Ljung-Box test is printed.

Usage

```
checkresiduals(object, lag, df=NULL, test, ...)
```

Arguments

`object`	Either a time series model, a forecast object, or a time series (assumed to be residuals).
`lag`	Number of lags to use in the Ljung-Box or Breusch-Godfrey test. If missing, it is set to `max(10,df+3)` for non-seasonal data, and `max(2m, df+3)` for seasonal data, where `df` is the degrees of freedom of the model, and `m` is the seasonal period of the data.
`df`	Number of degrees of freedom for fitted model, required for the Ljung-Box or Breusch-Godfrey test. Ignored if the degrees of freedom can be extracted from `object`.
`test`	Test to use for serial correlation. By default, if `object` is of class `lm`, then `test="BG"`. Otherwise, `test="LB"`.
`...`	Other arguments are passed to `ggtsdisplay`.

Value

None

Author(s)

Rob J Hyndman

See Also

ggtsdisplay, Box.test, bgtest

Examples

```
fit <- ets(WWWusage)
checkresiduals(fit)
```

---

croston — *Forecasts for intermittent demand using Croston's method*

Description

Returns forecasts and other information for Croston's forecasts applied to y.

Usage

```
croston(y, h=10, alpha=0.1, x=y)
```

Arguments

`y`	a numeric vector or time series
`h`	Number of periods for forecasting.
`alpha`	Value of alpha. Default value is 0.1.
`x`	Deprecated. Included for backwards compatibility.

Details

Based on Croston's (1972) method for intermittent demand forecasting, also described in Shenstone and Hyndman (2005). Croston's method involves using simple exponential smoothing (SES) on the non-zero elements of the time series and a separate application of SES to the times between non-zero elements of the time series. The smoothing parameters of the two applications of SES are assumed to be equal and are denoted by `alpha`.

Note that prediction intervals are not computed as Croston's method has no underlying stochastic model. The separate forecasts for the non-zero demands, and for the times between non-zero demands do have prediction intervals based on ETS(A,N,N) models.

Value

An object of class `"forecast"` is a list containing at least the following elements:

- `model` — A list containing information about the fitted model. The first element gives the model used for non-zero demands. The second element gives the model used for times between non-zero demands. Both elements are of class `forecast`.
- `method` — The name of the forecasting method as a character string
- `mean` — Point forecasts as a time series
- `x` — The original time series (either `object` itself or the time series used to create the model stored as `object`).
- `residuals` — Residuals from the fitted model. That is y minus fitted values.
- `fitted` — Fitted values (one-step forecasts)

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `croston` and associated functions.

Author(s)

Rob J Hyndman

References

Croston, J. (1972) "Forecasting and stock control for intermittent demands", *Operational Research Quarterly*, **23**(3), 289-303.

Shenstone, L., and Hyndman, R.J. (2005) "Stochastic models underlying Croston's method for intermittent demand forecasting". *Journal of Forecasting*, **24**, 389-402.

See Also

`ses`.

Examples

```
y <- rpois(20,lambda=.3)
fcast <- croston(y)
plot(fcast)
```

CV *Cross-validation statistic*

Description

Computes the leave-one-out cross-validation statistic (also known as PRESS – prediction residual sum of squares), AIC, corrected AIC, BIC and adjusted R^2 values for a linear model.

Usage

```
CV(obj)
```

Arguments

obj output from `lm` or `tslm`

Value

Numerical vector containing CV, AIC, AICc, BIC and AdjR2 values.

Author(s)

Rob J Hyndman

See Also

`AIC`

Examples

```
y <- ts(rnorm(120,0,3) + 20*sin(2*pi*(1:120)/12), frequency=12)
fit1 <- tslm(y ~ trend + season)
fit2 <- tslm(y ~ season)
CV(fit1)
CV(fit2)
```

CVar *k-fold Cross-Validation applied to an autoregressive model*

Description

`CVar` computes the errors obtained by applying an autoregressive modelling function to subsets of the time series `y` using k-fold cross-validation as described in Bergmeir, Hyndman and Koo (2015).

Usage

```
CVar(y, k=10, FUN=nnetar, cvtrace=FALSE, ...)
```

Arguments

y	Univariate time series
k	Number of folds to use for cross-validation.
FUN	Function to fit an autoregressive model. Currently, it only works with the `nnetar` function.
cvtrace	Provide progress information.
...	Other arguments are passed to `FUN`.

Value

A list containing information about the model and accuracy for each fold, plus other summary information computed across folds.

Author(s)

Gabriel Caceres and Rob J Hyndman

References

Bergmeir, C., Hyndman, R.J., Koo, B. (2015) A note on the validity of cross-validation for evaluating time series prediction. Monash working paper 10/15. `http://robjhyndman.com/working-papers/cv-time-series/`.

See Also

CV, tsCV.

Examples

```
modelcv <- CVar(lynx, k=5, lambda=0.15)
print(modelcv)
print(modelcv$fold1)
```

---

dm.test *Diebold-Mariano test for predictive accuracy*

Description

The Diebold-Mariano test compares the forecast accuracy of two forecast methods.

Usage

```
dm.test(e1, e2, alternative=c("two.sided","less","greater"),
    h=1, power=2)
```

Arguments

`e1`	Forecast errors from method 1.
`e2`	Forecast errors from method 2.
`alternative`	a character string specifying the alternative hypothesis, must be one of `"two.sided"` (default), `"greater"` or `"less"`. You can specify just the initial letter.
`h`	The forecast horizon used in calculating `e1` and `e2`.
`power`	The power used in the loss function. Usually 1 or 2.

Details

This function implements the modified test proposed by Harvey, Leybourne and Newbold (1997). The null hypothesis is that the two methods have the same forecast accuracy. For `alternative="less"`, the alternative hypothesis is that method 2 is less accurate than method 1. For `alternative="greater"`, the alternative hypothesis is that method 2 is more accurate than method 1. For `alternative="two.sided"`, the alternative hypothesis is that method 1 and method 2 have different levels of accuracy.

Value

A list with class `"htest"` containing the following components:

`statistic`	the value of the DM-statistic.
`parameter`	the forecast horizon and loss function power used in the test.
`alternative`	a character string describing the alternative hypothesis.
`p.value`	the p-value for the test.
`method`	a character string with the value "Diebold-Mariano Test".
`data.name`	a character vector giving the names of the two error series.

Author(s)

George Athanasopoulos

References

Diebold, F.X. and Mariano, R.S. (1995) Comparing predictive accuracy. *Journal of Business and Economic Statistics*, **13**, 253-263.

Harvey, D., Leybourne, S., & Newbold, P. (1997). Testing the equality of prediction mean squared errors. *International Journal of forecasting*, **13**(2), 281-291.

Examples

```
# Test on in-sample one-step forecasts
f1 <- ets(WWWusage)
f2 <- auto.arima(WWWusage)
accuracy(f1)
accuracy(f2)
dm.test(residuals(f1),residuals(f2),h=1)
```

```
# Test on out-of-sample one-step forecasts
f1 <- ets(WWWusage[1:80])
f2 <- auto.arima(WWWusage[1:80])
f1.out <- ets(WWWusage[81:100],model=f1)
f2.out <- Arima(WWWusage[81:100],model=f2)
accuracy(f1.out)
accuracy(f2.out)
dm.test(residuals(f1.out),residuals(f2.out),h=1)
```

---

dshw *Double-Seasonal Holt-Winters Forecasting*

Description

Returns forecasts using Taylor's (2003) Double-Seasonal Holt-Winters method.

Usage

```
dshw(y, period1=NULL, period2=NULL, h=2*max(period1,period2),
    alpha=NULL, beta=NULL, gamma=NULL, omega=NULL, phi=NULL,
    lambda=NULL, biasadj=FALSE, armethod=TRUE, model = NULL)
```

Arguments

y	Either an msts object with two seasonal periods or a numeric vector.
period1	Period of the shorter seasonal period. Only used if y is not an msts object.
period2	Period of the longer seasonal period. Only used if y is not an msts object.
h	Number of periods for forecasting.
alpha	Smoothing parameter for the level. If NULL, the parameter is estimated using least squares.
beta	Smoothing parameter for the slope. If NULL, the parameter is estimated using least squares.
gamma	Smoothing parameter for the first seasonal period. If NULL, the parameter is estimated using least squares.
omega	Smoothing parameter for the second seasonal period. If NULL, the parameter is estimated using least squares.
phi	Autoregressive parameter. If NULL, the parameter is estimated using least squares.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities. By default, the value is taken from what was used when fitting the model.
armethod	If TRUE, the forecasts are adjusted using an AR(1) model for the errors.
model	If it's specified, an existing model is applied to a new data set.

Details

Taylor's (2003) double-seasonal Holt-Winters method uses additive trend and multiplicative seasonality, where there are two seasonal components which are multiplied together. For example, with a series of half-hourly data, one would set `period1=48` for the daily period and `period2=336` for the weekly period. The smoothing parameter notation used here is different from that in Taylor (2003); instead it matches that used in Hyndman et al (2008) and that used for the `ets` function.

Value

An object of class `"forecast"`.

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `dshw`.

An object of class `"forecast"` is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model. That is x minus fitted values.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

References

Taylor, J.W. (2003) Short-term electricity demand forecasting using double seasonal exponential smoothing. *Journal of the Operational Reseach Society*, **54**, 799-805.

Hyndman, R.J., Koehler, A.B., Ord, J.K., and Snyder, R.D. (2008) *Forecasting with exponential smoothing: the state space approach*, Springer-Verlag. http://www.exponentialsmoothing.net.

See Also

`HoltWinters`, `ets`.

Examples

```
## Not run:
fcast <- dshw(taylor)
plot(fcast)

t <- seq(0,5,by=1/20)
```

```
x <- exp(sin(2*pi*t) + cos(2*pi*t*4) + rnorm(length(t),0,.1))
fit <- dshw(x,20,5)
plot(fit)

## End(Not run)
```

---

easter *Easter holidays in each season*

Description

Returns a vector of 0's and 1's or fractional results if Easter spans March and April in the observed time period. Easter is defined as the days from Good Friday to Easter Sunday inclusively, plus optionally Easter Monday if `easter.mon=TRUE`.

Usage

```
easter(x, easter.mon = FALSE)
```

Arguments

`x`	Monthly or quarterly time series
`easter.mon`	If TRUE, the length of Easter holidays includes Easter Monday.

Details

Useful for adjusting calendar effects.

Value

Time series

Author(s)

Earo Wang

Examples

```
easter(wineind, easter.mon = TRUE)
```

ets *Exponential smoothing state space model*

Description

Returns ets model applied to y.

Usage

```
ets(y, model="ZZZ", damped=NULL, alpha=NULL, beta=NULL, gamma=NULL,
    phi=NULL, additive.only=FALSE, lambda=NULL, biasadj=FALSE,
    lower=c(rep(0.0001,3), 0.8), upper=c(rep(0.9999,3),0.98),
    opt.crit=c("lik","amse","mse","sigma","mae"), nmse=3,
    bounds=c("both","usual","admissible"), ic=c("aicc","aic","bic"),
   restrict=TRUE, allow.multiplicative.trend=FALSE, use.initial.values=FALSE, ...)
```

Arguments

y	a numeric vector or time series
model	Usually a three-character string identifying method using the framework terminology of Hyndman et al. (2002) and Hyndman et al. (2008). The first letter denotes the error type ("A", "M" or "Z"); the second letter denotes the trend type ("N","A","M" or "Z"); and the third letter denotes the season type ("N","A","M" or "Z"). In all cases, "N"=none, "A"=additive, "M"=multiplicative and "Z"=automatically selected. So, for example, "ANN" is simple exponential smoothing with additive errors, "MAM" is multiplicative Holt-Winters' method with multiplicative errors, and so on. It is also possible for the model to be of class "ets", and equal to the output from a previous call to ets. In this case, the same model is fitted to y without re-estimating any smoothing parameters. See also the use.initial.values argument.
damped	If TRUE, use a damped trend (either additive or multiplicative). If NULL, both damped and non-damped trends will be tried and the best model (according to the information criterion ic) returned.
alpha	Value of alpha. If NULL, it is estimated.
beta	Value of beta. If NULL, it is estimated.
gamma	Value of gamma. If NULL, it is estimated.
phi	Value of phi. If NULL, it is estimated.
additive.only	If TRUE, will only consider additive models. Default is FALSE.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated. When lambda is specified, additive.only is set to TRUE.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.

`lower`	Lower bounds for the parameters (alpha, beta, gamma, phi)
`upper`	Upper bounds for the parameters (alpha, beta, gamma, phi)
`opt.crit`	Optimization criterion. One of "mse" (Mean Square Error), "amse" (Average MSE over first `nmse` forecast horizons), "sigma" (Standard deviation of residuals), "mae" (Mean of absolute residuals), or "lik" (Log-likelihood, the default).
`nmse`	Number of steps for average multistep MSE (1<=`nmse`<=30).
`bounds`	Type of parameter space to impose: `"usual"` indicates all parameters must lie between specified lower and upper bounds; `"admissible"` indicates parameters must lie in the admissible space; `"both"` (default) takes the intersection of these regions.
`ic`	Information criterion to be used in model selection.
`restrict`	If `TRUE` (default), the models with infinite variance will not be allowed.
`allow.multiplicative.trend`	If `TRUE`, models with multiplicative trend are allowed when searching for a model. Otherwise, the model space excludes them. This argument is ignored if a multiplicative trend model is explicitly requested (e.g., using `model="MMN"`).
`use.initial.values`	If `TRUE` and `model` is of class `"ets"`, then the initial values in the model are also not re-estimated.
`...`	Other undocumented arguments.

Details

Based on the classification of methods as described in Hyndman et al (2008).

The methodology is fully automatic. The only required argument for ets is the time series. The model is chosen automatically if not specified. This methodology performed extremely well on the M3-competition data. (See Hyndman, et al, 2002, below.)

Value

An object of class "`ets`".

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `ets` and associated functions.

Author(s)

Rob J Hyndman

References

Hyndman, R.J., Koehler, A.B., Snyder, R.D., and Grose, S. (2002) "A state space framework for automatic forecasting using exponential smoothing methods", *International J. Forecasting*, **18**(3), 439–454.

Hyndman, R.J., Akram, Md., and Archibald, B. (2008) "The admissible parameter space for exponential smoothing models". *Annals of Statistical Mathematics*, **60**(2), 407–426.

Hyndman, R.J., Koehler, A.B., Ord, J.K., and Snyder, R.D. (2008) *Forecasting with exponential smoothing: the state space approach*, Springer-Verlag. http://www.exponentialsmoothing.net.

See Also

HoltWinters, rwf, Arima.

Examples

```
fit <- ets(USAccDeaths)
plot(forecast(fit))
```

---

findfrequency — *Find dominant frequency of a time series*

Description

`findfrequency` returns the period of the dominant frequency of a time series. For seasonal data, it will return the seasonal period. For cyclic data, it will return the average cycle length.

Usage

```
findfrequency(x)
```

Arguments

x	a numeric vector or time series

Details

The dominant frequency is determined from a spectral analysis of the time series. First, a linear trend is removed, then the spectral density function is estimated from the best fitting autoregressive model (based on the AIC). If there is a large (possibly local) maximum in the spectral density function at frequency f, then the function will return the period $1/f$ (rounded to the nearest integer). If no such dominant frequency can be found, the function will return 1.

Value

an integer value

Author(s)

Rob J Hyndman

Examples

```
findfrequency(USAccDeaths) # Monthly data
findfrequency(taylor) # Half-hourly data
findfrequency(lynx) # Annual data
```

`fitted.Arima` *h-step in-sample forecasts for time series models.*

Description

Returns h-step forecasts for the data used in fitting the model.

Usage

```
## S3 method for class 'Arima'
fitted(object, h=1, ...)
## S3 method for class 'fracdiff'
fitted(object, h=1, ...)
## S3 method for class 'bats'
fitted(object, h=1, ...)
## S3 method for class 'tbats'
fitted(object, h=1, ...)
## S3 method for class 'ets'
fitted(object, h=1, ...)
## S3 method for class 'nnetar'
fitted(object, h=1, ...)
```

Arguments

`object`	An object of class "Arima", "bats", "tbats", "ets" or "nnetar".
`h`	The number of steps to forecast ahead.
`...`	Other arguments.

Value

A time series of the h-step forecasts.

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

See Also

`forecast.Arima`, `forecast.bats`, `forecast.tbats`, `forecast.ets`, `forecast.nnetar`, `residuals.Arima`, `residuals.bats`, `residuals.tbats`, `residuals.ets`, `residuals.nnetar`.

Examples

```
fit <- ets(WWWusage)
plot(WWWusage)
lines(fitted(fit), col='red')
lines(fitted(fit, h=2), col='green')
lines(fitted(fit, h=3), col='blue')
legend("topleft", legend=paste("h =",1:3), col=2:4, lty=1)
```

forecast *Forecasting time series*

Description

forecast is a generic function for forecasting from time series or time series models. The function invokes particular *methods* which depend on the class of the first argument.

For example, the function forecast.Arima makes forecasts based on the results produced by arima.

If model=NULL,the function forecast.ts makes forecasts using ets models (if the data are non-seasonal or the seasonal period is 12 or less) or stlf (if the seasonal period is 13 or more).

If model is not NULL, forecast.ts will apply the model to the object time series, and then generate forecasts accordingly.

Usage

```
forecast(object,...)
## S3 method for class 'ts'
forecast(object, h = ifelse(frequency(object) > 1, 2 * frequency(object), 10) ,
       level=c(80,95), fan=FALSE, robust=FALSE, lambda=NULL, find.frequency=FALSE,
         allow.multiplicative.trend=FALSE, model=NULL,...)
```

Arguments

object	a time series or time series model for which forecasts are required
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.
robust	If TRUE, the function is robust to missing values and outliers in object. This argument is only valid when object is of class ts.
lambda	Box-Cox transformation parameter.
find.frequency	If TRUE, the function determines the appropriate period, if the data is of unknown period.
allow.multiplicative.trend	If TRUE, then ETS models with multiplicative trends are allowed. Otherwise, only additive or no trend ETS models are permitted.
model	An object describing a time series model; e.g., one of of class ets, Arima, bats, tbats, or nnetar.
...	Additional arguments affecting the forecasts produced. If model=NULL, forecast.ts passes these to ets or stlf depending on the frequency of the time series. If model is not NULL, the arguments are passed to the relevant modelling function.

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessors functions fitted.values and residuals extract various useful features of the value returned by forecast$model.

An object of class "forecast" is a list usually containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either object itself or the time series used to create the model stored as object).
residuals	Residuals from the fitted model. For models with additive errors, the residuals will be x minus the fitted values.
fitted	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

Other functions which return objects of class "forecast" are forecast.ets, forecast.Arima, forecast.HoltWinters, forecast.StructTS, meanf, rwf, splinef, thetaf, croston, ses, holt, hw.

Examples

```
WWWusage %>% forecast %>% plot
fit <- ets(window(WWWusage, end=60))
fc <- forecast(WWWusage, model=fit)
```

forecast.Arima *Forecasting using ARIMA or ARFIMA models*

Description

Returns forecasts and other information for univariate ARIMA models.

Usage

```
## S3 method for class 'Arima'
forecast(object, h=ifelse(object$arma[5]>1,2*object$arma[5],10),
    level=c(80,95), fan=FALSE, xreg=NULL, lambda=object$lambda,
    bootstrap=FALSE, npaths=5000, biasadj=NULL, ...)
## S3 method for class 'ar'
forecast(object, h=10, level=c(80,95), fan=FALSE, lambda=NULL,
    bootstrap=FALSE, npaths=5000, biasadj=FALSE, ...)
## S3 method for class 'fracdiff'
forecast(object, h=10, level=c(80,95), fan=FALSE,
    lambda=object$lambda, biasadj=NULL, ...)
```

Arguments

`object`	An object of class "`Arima`", "`ar`" or "`fracdiff`". Usually the result of a call to `arima`, `auto.arima`, `ar`, `arfima` or `fracdiff`.
`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`.
`level`	Confidence level for prediction intervals.
`fan`	If `TRUE`, level is set to `seq(51,99,by=3)`. This is suitable for fan plots.
`xreg`	Future values of an regression variables (for class `Arima` objects only).
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities. By default, the value is taken from what was used when fitting the model.
`bootstrap`	If `TRUE`, then prediction intervals computed using simulation with resampled errors.
`npaths`	Number of sample paths used in computing simulated prediction intervals when `bootstrap=TRUE`.
`...`	Other arguments.

Details

For `Arima` or `ar` objects, the function calls `predict.Arima` or `predict.ar` and constructs an object of class "`forecast`" from the results. For `fracdiff` objects, the calculations are all done within `forecast.fracdiff` using the equations given by Peiris and Perera (1988).

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by forecast.Arima.

An object of class "forecast" is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either object itself or the time series used to create the model stored as object).
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

References

Peiris, M. & Perera, B. (1988), On prediction with fractionally differenced ARIMA models, *Journal of Time Series Analysis*, **9**(3), 215-220.

See Also

predict.Arima, predict.ar, auto.arima, Arima, arima, ar, arfima.

Examples

```
fit <- Arima(WWWusage,c(3,1,0))
plot(forecast(fit))

library(fracdiff)
x <- fracdiff.sim( 100, ma=-.4, d=.3)$series
fit <- arfima(x)
plot(forecast(fit,h=30))
```

forecast.baggedETS *Forecasting using the bagged ETS method*

Description

Returns forecasts and other information for bagged ETS models.

Usage

```
## S3 method for class 'baggedETS'
forecast(object,
    h=ifelse(frequency(object$x)>1, 2*frequency(object$x), 10), ...)
```

Arguments

`object`	An object of class "baggedETS" resulting from a call to `baggedETS`.
`h`	Number of periods for forecasting.
`...`	Additional arguments passed to `ets`

Details

Intervals are calculated as min and max values over the point forecasts from the ETS models in the ensemble. I.e., the intervals are not prediction intervals, but give an indication of how different the forecasts within the ensemble are.

Value

An object of class "forecast".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

An object of class "forecast" is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`xreg`	The external regressors used in fitting (if given).
`residuals`	Residuals from the fitted model. That is x minus fitted values.
`fitted`	Fitted values (one-step forecasts)
`...`	Other arguments

Author(s)

Christoph Bergmeir, Fotios Petropoulos

References

Bergmeir, C., R. J. Hyndman, and J. M. Benitez (2016). Bagging Exponential Smoothing Methods using STL Decomposition and Box-Cox Transformation. International Journal of Forecasting 32, 303-312.

See Also

baggedETS.

Examples

```
fit <- baggedETS(WWWusage)
fcast <- forecast(fit)
plot(fcast)
```

---

forecast.bats *Forecasting using BATS and TBATS models*

Description

Forecasts h steps ahead with a BATS model. Prediction intervals are also produced.

Usage

```
## S3 method for class 'bats'
forecast(object, h, level=c(80,95), fan=FALSE, biasadj=NULL, ...)
## S3 method for class 'tbats'
forecast(object, h, level=c(80,95), fan=FALSE, biasadj=NULL, ...)
```

Arguments

object	An object of class "bats". Usually the result of a call to bats.
h	Number of periods for forecasting. Default value is twice the largest seasonal period (for seasonal data) or ten (for non-seasonal data).
level	Confidence level for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
...	Other arguments, currently ignored.

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by forecast.bats.

An object of class "forecast" is a list containing at least the following elements:

model	A copy of the bats object
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either object itself or the time series used to create the model stored as object).
residuals	Residuals from the fitted model.
fitted	Fitted values (one-step forecasts)

Author(s)

Slava Razbash and Rob J Hyndman

References

De Livera, A.M., Hyndman, R.J., & Snyder, R. D. (2011), Forecasting time series with complex seasonal patterns using exponential smoothing, *Journal of the American Statistical Association*, **106**(496), 1513-1527.

See Also

bats, tbats,forecast.ets.

Examples

```
## Not run:
fit <- bats(USAccDeaths)
plot(forecast(fit))

taylor.fit <- bats(taylor)
plot(forecast(taylor.fit))

## End(Not run)
```

forecast.ets *Forecasting using ETS models*

Description

Returns forecasts and other information for univariate ETS models.

Usage

```
## S3 method for class 'ets'
forecast(object, h=ifelse(object$m>1, 2*object$m, 10),
    level=c(80,95), fan=FALSE, simulate=FALSE, bootstrap=FALSE,
    npaths=5000, PI=TRUE, lambda=object$lambda, biasadj=NULL, ...)
```

Arguments

`object`	An object of class "`ets`". Usually the result of a call to `ets`.
`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.
`simulate`	If TRUE, prediction intervals produced by simulation rather than using analytic formulae.
`bootstrap`	If TRUE, and if `simulate=TRUE`, then simulation uses resampled errors rather than normally distributed errors.
`npaths`	Number of sample paths used in computing simulated prediction intervals.
`PI`	If TRUE, prediction intervals are produced, otherwise only point forecasts are calculated. If `PI` is FALSE, then `level`, `fan`, `simulate`, `bootstrap` and `npaths` are all ignored.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities. By default, the value is taken from what was used when fitting the model.
`...`	Other arguments.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `forecast.ets`.

An object of class `"forecast"` is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either `object` itself or the time series used to create the model stored as `object`).
residuals	Residuals from the fitted model. For models with additive errors, the residuals are x - fitted values. For models with multiplicative errors, the residuals are equal to x /(fitted values) - 1.
fitted	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

ets, ses, holt, hw.

Examples

```
fit <- ets(USAccDeaths)
plot(forecast(fit,h=48))
```

`forecast.HoltWinters` *Forecasting using Holt-Winters objects*

Description

Returns forecasts and other information for univariate Holt-Winters time series models.

Usage

```
## S3 method for class 'HoltWinters'
forecast(object, h=ifelse(frequency(object$x)>1,2*frequency(object$x),10),
    level=c(80,95),fan=FALSE,lambda=NULL, biasadj=NULL,...)
```

Arguments

`object`	An object of class "`HoltWinters`". Usually the result of a call to `HoltWinters`.
`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.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`...`	Other arguments.

Details

This function calls `predict.HoltWinters` and constructs an object of class "`forecast`" from the results.

It is included for completeness, but the `ets` is recommended for use instead of `HoltWinters`.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `forecast.HoltWinters`.

An object of class `"forecast"` is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

predict.HoltWinters, HoltWinters.

Examples

```
fit <- HoltWinters(WWWusage,gamma=FALSE)
plot(forecast(fit))
```

---

forecast.lm *Forecast a linear model with possible time series components*

Description

forecast.lm is used to predict linear models, especially those involving trend and seasonality components.

Usage

```
## S3 method for class 'lm'
forecast(object, newdata, h=10, level=c(80,95), fan=FALSE,
    lambda=object$lambda, biasadj=NULL, ts=TRUE, ...)
```

Arguments

object	Object of class "lm", usually the result of a call to lm or tslm.
newdata	An optional data frame in which to look for variables with which to predict. If omitted, it is assumed that the only variables are trend and season, and h forecasts are produced.
level	Confidence level for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
h	Number of periods for forecasting. Ignored if newdata present.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
ts	If TRUE, the forecasts will be treated as time series provided the original data is a time series; the newdata will be interpreted as related to the subsequent time periods. If FALSE, any time series attributes of the original data will be ignored.
...	Other arguments passed to predict.lm().

Details

forecast.lm is largely a wrapper for predict.lm() except that it allows variables "trend" and "season" which are created on the fly from the time series characteristics of the data. Also, the output is reformatted into a forecast object.

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by forecast.lm.

An object of class "forecast" is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The historical data for the response variable.
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values

Author(s)

Rob J Hyndman

See Also

tslm, lm.

Examples

```
y <- ts(rnorm(120,0,3) + 1:120 + 20*sin(2*pi*(1:120)/12), frequency=12)
fit <- tslm(y ~ trend + season)
plot(forecast(fit, h=20))
```

---

forecast.mlm — *Forecast a multiple linear model with possible time series components*

Description

forecast.mlm is used to predict multiple linear models, especially those involving trend and seasonality components.

Usage

```
## S3 method for class 'mlm'
forecast(object, newdata, h = 10, level = c(80, 95),
    fan = FALSE, lambda = object$lambda, biasadj = NULL, ts = TRUE, ...)
```

Arguments

object	Object of class "mlm", usually the result of a call to lm or tslm.
newdata	An optional data frame in which to look for variables with which to predict. If omitted, it is assumed that the only variables are trend and season, and h forecasts are produced.
level	Confidence level for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
h	Number of periods for forecasting. Ignored if newdata present.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
ts	If TRUE, the forecasts will be treated as time series provided the original data is a time series; the newdata will be interpreted as related to the subsequent time periods. If FALSE, any time series attributes of the original data will be ignored.
...	Other arguments passed to forecast.lm().

Details

forecast.mlm is largely a wrapper for forecast.lm() except that it allows forecasts to be generated on multiple series. Also, the output is reformatted into a mforecast object.

Value

An object of class "mforecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by forecast.lm.

An object of class "mforecast" is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a multivariate time series
lower	Lower limits for prediction intervals of each series
upper	Upper limits for prediction intervals of each series
level	The confidence values associated with the prediction intervals
x	The historical data for the response variable.
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values

Author(s)

Mitchell O'Hara-Wild

See Also

tslm, forecast.lm, lm.

Examples

```
lungDeaths <- cbind(mdeaths, fdeaths)
fit <- tslm(lungDeaths ~ trend + season)
fcast <- forecast(fit, h=10)

carPower <- as.matrix(mtcars[,c("qsec","hp")])
carmpg <- mtcars[,"mpg"]
fit <- lm(carPower ~ carmpg)
fcast <- forecast(fit, newdata=data.frame(carmpg=30))
```

---

forecast.nnetar *Forecasting using neural network models*

Description

Returns forecasts and other information for univariate neural network models.

Usage

```
## S3 method for class 'nnetar'
forecast(object, h=ifelse(object$m > 1, 2 * object$m, 10),
    PI=FALSE, level=c(80, 95), fan=FALSE, xreg=NULL,
lambda=object$lambda, bootstrap=FALSE, npaths=1000, innov=NULL, ...)
```

Arguments

object	An object of class "nnetar" resulting from a call to arima.
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.
PI	If TRUE, prediction intervals are produced, otherwise only point forecasts are calculated. If PI is FALSE, then level, fan, bootstrap and npaths are all ignored.
level	Confidence level for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
xreg	Future values of external regressor variables.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.

`bootstrap`	If `TRUE`, then prediction intervals computed using simulations with resampled residuals rather than normally distributed errors. Ignored if `innov` is not `NULL`.
`npaths`	Number of sample paths used in computing simulated prediction intervals.
`innov`	Values to use as innovations for prediction intervals. Must be a matrix with `h` rows and `npaths` columns (vectors are coerced into a matrix). If present, `bootstrap` is ignored.
`...`	Additional arguments passed to `simulate.nnetar`

Details

Prediction intervals are calculated through simulations and can be slow. Note that if the network is too complex and overfits the data, the residuals can be arbitrarily small; if used for prediction interval calculations, they could lead to misleadingly small values.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `forecast.nnetar`.

An object of class "`forecast`" is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`xreg`	The external regressors used in fitting (if given).
`residuals`	Residuals from the fitted model. That is x minus fitted values.
`fitted`	Fitted values (one-step forecasts)
`...`	Other arguments

Author(s)

Rob J Hyndman

See Also

`nnetar`.

Examples

```
fit <- nnetar(lynx)
fcast <- forecast(fit)
plot(fcast)
```

---

forecast.stl *Forecasting using stl objects*

Description

Forecasts of STL objects are obtained by applying a non-seasonal forecasting method to the seasonally adjusted data and re-seasonalizing using the last year of the seasonal component.

Usage

```
stlm(y, s.window=7, robust=FALSE, method=c("ets","arima"), modelfunction=NULL,
     model=NULL, etsmodel="ZZN", lambda=NULL, biasadj=FALSE, xreg=NULL,
     allow.multiplicative.trend=FALSE, x=y, ...)
stlf(y, h=frequency(x)*2, s.window=7, t.window=NULL, robust=FALSE,
    lambda=NULL, biasadj=FALSE, x=y, ...)
## S3 method for class 'stlm'
forecast(object, h = 2*object$m,
level = c(80, 95), fan = FALSE, lambda=object$lambda, biasadj=NULL, newxreg=NULL,
  allow.multiplicative.trend=FALSE, ...)
## S3 method for class 'stl'
forecast(object, method=c("ets","arima","naive","rwdrift"),
    etsmodel="ZZN", forecastfunction=NULL,
    h=frequency(object$time.series)*2, level=c(80,95),
    fan=FALSE, lambda=NULL, biasadj=NULL, xreg=NULL, newxreg=NULL,
    allow.multiplicative.trend=FALSE, ...)
```

Arguments

`y`	A univariate numeric time series of class `ts`
`object`	An object of class `stl` or `stlm`. Usually the result of a call to `stl` or `stlm`.
`method`	Method to use for forecasting the seasonally adjusted series.
`modelfunction`	An alternative way of specifying the function for modelling the seasonally adjusted series. If `modelfunction` is not `NULL`, then `method` is ignored. Otherwise `method` is used to specify the time series model to be used.
`model`	Output from a previous call to `stlm`. If a `stlm` model is passed, this same model is fitted to y without re-estimating any parameters.
`forecastfunction`	An alternative way of specifying the function for forecasting the seasonally adjusted series. If `forecastfunction` is not `NULL`, then `method` is ignored. Otherwise `method` is used to specify the forecasting method to be used.

etsmodel	The ets model specification passed to ets. By default it allows any non-seasonal model. If method!="ets", this argument is ignored.
xreg	Historical regressors to be used in auto.arima() when method=="arima".
newxreg	Future regressors to be used in forecast.Arima().
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.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before decomposition and back-transformed after forecasts are computed.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
s.window	Either the character string "periodic" or the span (in lags) of the loess window for seasonal extraction.
t.window	A number to control the smoothness of the trend. See stl for details.
robust	If TRUE, robust fitting will used in the loess procedure within stl.
allow.multiplicative.trend	If TRUE, then ETS models with multiplicative trends are allowed. Otherwise, only additive or no trend ETS models are permitted.
x	Deprecated. Included for backwards compatibility.
...	Other arguments passed to forecast.stl, modelfunction or forecastfunction.

Details

stlm takes a time series y, applies an STL decomposition, and models the seasonally adjusted data using the model passed as modelfunction or specified using method. It returns an object that includes the original STL decomposition and a time series model fitted to the seasonally adjusted data. This object can be passed to the forecast.stlm for forecasting.

forecast.stlm forecasts the seasonally adjusted data, then re-seasonalizes the results by adding back the last year of the estimated seasonal component.

stlf combines stlm and forecast.stlm. It takes a ts argument, applies an STL decomposition, models the seasonally adjusted data, reseasonalizes, and returns the forecasts. However, it allows more general forecasting methods to be specified via forecastfunction.

forecast.stl is similar to stlf except that it takes the STL decomposition as the first argument, instead of the time series.

Note that the prediction intervals ignore the uncertainty associated with the seasonal component. They are computed using the prediction intervals from the seasonally adjusted series, which are then reseasonalized using the last year of the seasonal component. The uncertainty in the seasonal component is ignored.

The time series model for the seasonally adjusted data can be specified in stlm using either method or modelfunction. The method argument provides a shorthand way of specifying modelfunction for a few special cases. More generally, modelfunction can be any function with first argument a ts object, that returns an object that can be passed to forecast. For example, forecastfunction=ar uses the ar function for modelling the seasonally adjusted series.

The forecasting method for the seasonally adjusted data can be specified in stlf and forecast.stl using either method or forecastfunction. The method argument provides a shorthand way of specifying forecastfunction for a few special cases. More generally, forecastfunction can be any function with first argument a ts object, and other h and level, which returns an object of class forecast. For example, forecastfunction=thetaf uses the thetaf function for forecasting the seasonally adjusted series.

Value

stlm returns an object of class stlm. The other functions return objects of class forecast.

There are many methods for working with forecast objects including summary to obtain and print a summary of the results, while plot produces a plot of the forecasts and prediction intervals. The generic accessor functions fitted.values and residuals extract useful features.

Author(s)

Rob J Hyndman

See Also

stl, forecast.ets, forecast.Arima.

Examples

```
tsmod <- stlm(USAccDeaths, modelfunction=ar)
plot(forecast(tsmod, h=36))

plot(stlf(AirPassengers, lambda=0))

decomp <- stl(USAccDeaths,s.window="periodic")
plot(forecast(decomp))
```

---

forecast.StructTS *Forecasting using Structural Time Series models*

Description

Returns forecasts and other information for univariate structural time series models.

Usage

```
## S3 method for class 'StructTS'
forecast(object,
    h=ifelse(object$coef["epsilon"] > 1e-10, 2*object$xtsp[3],10),
    level=c(80,95), fan=FALSE, lambda=NULL, biasadj=NULL, ...)
```

Arguments

`object`	An object of class "`StructTS`". Usually the result of a call to `StructTS`.
`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.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`...`	Other arguments.

Details

This function calls `predict.StructTS` and constructs an object of class "`forecast`" from the results.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `forecast.StructTS`.

An object of class `"forecast"` is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model. That is x minus fitted values.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

`StructTS`.

Examples

```
fit <- StructTS(WWWusage,"level")
plot(forecast(fit))
```

`fourier` *Fourier terms for modelling seasonality*

Description

`fourier` returns a matrix containing terms from a Fourier series, up to order `K`, suitable for use in `Arima`, `auto.arima`, or `tslm`.

`fourierf` is deprecated, instead use the `h` argument in `fourier`.

Usage

```
fourier(x,K,h)
```

Arguments

`x`	Seasonal time series: a `ts` or a `msts` object
`K`	Maximum order(s) of Fourier terms
`h`	Number of periods ahead to forecast (optional)

Details

The period of the Fourier terms is determined from the time series characteristics of `x`. When `h` is missing, the length of `x` also determines the number of rows for the matrix returned by `fourier`. Otherwise, the value of `h` determines the number of rows for the matrix returned by `fourier`, typically used for forecasting. The values within `x` are not used.

When `x` is a `ts` object, the value of `K` should be an integer and specifies the number of sine and cosine terms to return. Thus, the matrix returned has `2*K` columns.

When `x` is a `msts` object, then `K` should be a vector of integers specifying the number of sine and cosine terms for each of the seasonal periods. Then the matrix returned will have `2*sum(K)` columns.

Value

Numerical matrix.

Author(s)

Rob J Hyndman

See Also

`seasonaldummy`

Examples

```
library(ggplot2)

# Using Fourier series for a "ts" object
# K is chosen to minimize the AICc
deaths.model  <- auto.arima(USAccDeaths, xreg=fourier(USAccDeaths,K=5), seasonal=FALSE)
deaths.fcast <- forecast(deaths.model, xreg=fourier(USAccDeaths, K=5, h=36))
autoplot(deaths.fcast) + xlab("Year")

# Using Fourier series for a "msts" object
taylor.lm <- tslm(taylor ~ fourier(taylor, K = c(3, 3)))
taylor.fcast <- forecast(taylor.lm,
    data.frame(fourier(taylor, K = c(3, 3), h = 270)))
autoplot(taylor.fcast)
```

---

gas *Australian monthly gas production*

Description

Australian monthly gas production: 1956–1995.

Usage

```
gas
```

Format

Time series data

Source

Australian Bureau of Statistics.

Examples

```
plot(gas)
seasonplot(gas)
tsdisplay(gas)
```

geom_forecast *Forecast plot*

Description

Generates forecasts from forecast.ts and adds them to the plot. Forecasts can be modified via sending forecast specific arguments above.

Multivariate forecasting is supported by having each time series on a different group.

You can also pass geom_forecast a forecast object to add it to the plot.

The aesthetics required for the forecasting to work includes forecast observations on the y axis, and the time of the observations on the x axis. Refer to the examples below. To automatically set up aesthetics, use autoplot.

Usage

```
geom_forecast(mapping = NULL, data = NULL, stat = "forecast",
    position = "identity", na.rm = FALSE, show.legend = NA,
    inherit.aes = TRUE, PI=TRUE, showgap=TRUE, series=NULL, ...)
```

Arguments

mapping	Set of aesthetic mappings created by aes or aes_. If specified and inherit.aes = TRUE (the default), it is combined with the default mapping at the top level of the plot. You must supply mapping if there is no plot mapping.
data	The data to be displayed in this layer. There are three options: If NULL, the default, the data is inherited from the plot data as specified in the call to ggplot. A data.frame, or other object, will override the plot data. All objects will be fortified to produce a data frame. See fortify for which variables will be created. A function will be called with a single argument, the plot data. The return value must be a data.frame, and will be used as the layer data.
stat	The stat object to use calculate the data.
position	Position adjustment, either as a string, or the result of a call to a position adjustment function.
na.rm	If FALSE (the default), removes missing values with a warning. If TRUE silently removes missing values.
show.legend	logical. Should this layer be included in the legends? NA, the default, includes if any aesthetics are mapped. FALSE never includes, and TRUE always includes.
inherit.aes	If FALSE, overrides the default aesthetics, rather than combining with them. This is most useful for helper functions that define both data and aesthetics and shouldn't inherit behaviour from the default plot specification, e.g. borders.
PI	If FALSE, confidence intervals will not be plotted, giving only the forecast line.

showgap	If showgap=FALSE, the gap between the historical observations and the forecasts is removed.
series	Matches an unidentified forecast layer with a coloured object on the plot.
...	Additional arguments for forecast.ts, other arguments are passed on to layer. These are often aesthetics, used to set an aesthetic to a fixed value, like color = "red" or alpha = .5. They may also be parameters to the paired geom/stat.

Value

A layer for a ggplot graph.

Author(s)

Mitchell O'Hara-Wild

See Also

forecast, ggproto

Examples

```
## Not run:
library(ggplot2)
autoplot(USAccDeaths) + geom_forecast()

lungDeaths <- cbind(mdeaths, fdeaths)
autoplot(lungDeaths) + geom_forecast()

# Using fortify.ts
p <- ggplot(aes(x=x, y=y), data=USAccDeaths)
p <- p + geom_line()
p + geom_forecast()

# Without fortify.ts
data <- data.frame(USAccDeaths=as.numeric(USAccDeaths), time=as.numeric(time(USAccDeaths)))
p <- ggplot(aes(x=time, y=USAccDeaths), data=data)
p <- p + geom_line()
p + geom_forecast()

p + geom_forecast(h=60)
p <- ggplot(aes(x=time, y=USAccDeaths), data=data)
p + geom_forecast(level=c(70,98))
p + geom_forecast(level=c(70,98),colour="lightblue")

#Add forecasts to multivariate series with colour groups
lungDeaths <- cbind(mdeaths, fdeaths)
autoplot(lungDeaths) + geom_forecast(forecast(mdeaths), series="mdeaths")

## End(Not run)
```

`getResponse` *Get response variable from time series model.*

Description

`getResponse` is a generic function for extracting the historical data from a time series model (including `Arima`, `ets`, `ar`, `fracdiff`), a linear model of class `lm`, or a forecast object. The function invokes particular *methods* which depend on the class of the first argument.

Usage

```
getResponse(object,...)
```

Arguments

`object`	a time series model or forecast object.
`...`	Additional arguments that are ignored.

Value

A numerical vector or a time series object of class `ts`.

Author(s)

Rob J Hyndman

`gghistogram` *Histogram with optional normal and kernel density functions*

Description

Plots a histogram and density estimates using ggplot.

Usage

```
gghistogram(x, add.normal=FALSE, add.kde=FALSE, add.rug=TRUE, bins, boundary=0)
```

Arguments

`x`	a numerical vector.
`add.normal`	Add a normal density function for comparison
`add.kde`	Add a kernel density estimate for comparison
`add.rug`	Add a rug plot on the horizontal axis
`bins`	The number of bins to use for the histogram. Selected by default using the Friedman-Diaconis rule given by `nclass.FD`
`boundary`	A boundary between two bins.
`...`	Not used (for consistency with lag.plot)

Value

None.

Author(s)

Rob J Hyndman

See Also

hist, geom_histogram

Examples

```
gghistogram(lynx, add.kde=TRUE)
```

---

gglagplot *Time series lag ggplots*

Description

Plots a lag plot using ggplot.

“gglagplot” will plot time series against lagged versions of themselves. Helps visualising ’auto-dependence’ even when auto-correlations vanish.

“gglagchull” will layer convex hulls of the lags, layered on a single plot. This helps visualise the change in ’auto-dependence’ as lags increase.

Usage

```
gglagplot(x, lags=ifelse(frequency(x)>9, 16, 9),
set.lags=1:lags, diag=TRUE, diag.col="gray", do.lines=TRUE, colour=TRUE,
continuous=frequency(x)>12, labels=FALSE, seasonal=TRUE, ...)
gglagchull(x, lags=ifelse(frequency(x)>1, min(12,frequency(x)), 4),
set.lags=1:lags, diag=TRUE, diag.col="gray", ...)
```

Arguments

x	a time series object (type ts).
lags	number of lag plots desired, see arg set.lags.
set.lags	vector of positive integers specifying which lags to use.
diag	logical indicating if the x=y diagonal should be drawn.
diag.col	color to be used for the diagonal if(diag).
do.lines	if TRUE, lines will be drawn, otherwise points will be drawn.
colour	logical indicating if lines should be coloured.
continuous	Should the colour scheme for years be continuous or discrete?

`labels`	logical indicating if labels should be used.
`seasonal`	Should the line colour be based on seasonal characteristics (TRUE), or sequential (FALSE).
`...`	Not used (for consistency with lag.plot)

Value

None.

Author(s)

Mitchell O'Hara-Wild

See Also

`lag.plot`

Examples

```
gglagplot(woolyrnq)
gglagplot(woolyrnq,seasonal=FALSE)

gglagchull(woolyrnq)

lungDeaths <- cbind(mdeaths, fdeaths)
gglagplot(lungDeaths, lags=2)
gglagchull(lungDeaths, lags=6)
```

---

ggmonthplot *Create a seasonal subseries ggplot*

Description

Plots a subseries plot using ggplot. Each season is plotted as a separate mini time series. The blue lines represent the mean of the observations within each season.

The `ggmonthplot` function is simply a wrapper for `ggsubseriesplot` as a convenience for users familiar with `monthplot`.

Usage

```
ggsubseriesplot(x, labels = NULL, times = time(x), phase = cycle(x), ...)
ggmonthplot(x, labels = NULL, times = time(x), phase = cycle(x), ...)
```

Arguments

`x`	a time series object (type `ts`).
`labels`	A vector of labels to use for each 'season'
`times`	A vector of times for each observation
`phase`	A vector of seasonal components
`...`	Not used (for consistency with monthplot)

Value

Returns an object of class `ggplot`.

Author(s)

Mitchell O'Hara-Wild

See Also

`monthplot`

Examples

```
ggsubseriesplot(AirPassengers)
ggsubseriesplot(woolyrnq)
```

`gold` *Daily morning gold prices*

Description

Daily morning gold prices in US dollars. 1 January 1985 – 31 March 1989.

Usage

```
data(gold)
```

Format

Time series data

Source

Time Series Data Library. `http://data.is/TSDLdemo`

Examples

```
tsdisplay(gold)
```

is.constant *Is an object constant?*

Description

Returns true if the object's numerical values do not vary.

Usage

```
is.constant(x)
```

Arguments

x	object to be tested

is.ets *Is an object a particular model type?*

Description

Returns true if the model object is of a particular type

Usage

```
is.ets(x)
is.acf(x)
is.Arima(x)
is.bats(x)
is.Arima(x)
is.bats(x)
is.ets(x)
is.nnetar(x)
is.nnetarmodels(x)
is.baggedETS(x)
is.stlm(x)
```

Arguments

x	object to be tested

`is.forecast` *Is an object a particular forecast type?*

Description

Returns true if the forecast object is of a particular type

Usage

```
is.forecast(x)
is.mforecast(x)
is.splineforecast(x)
```

Arguments

`x`	object to be tested

`ma` *Moving-average smoothing*

Description

`ma` computes a simple moving average smoother of a given time series.

Usage

```
ma(x, order, centre=TRUE)
```

Arguments

`x`	Univariate time series
`order`	Order of moving average smoother
`centre`	If TRUE, then the moving average is centred for even orders.

Details

The moving average smoother averages the nearest `order` periods of each observation. As neighbouring observations of a time series are likely to be similar in value, averaging eliminates some of the randomness in the data, leaving a smooth trend-cycle component.

$$\hat{T}_t = \frac{1}{m} \sum_{j=-k}^{k} y_{t+j}$$

where $k = \frac{m-1}{2}$

When an even `order` is specified, the observations averaged will include one more observation from the future than the past (k is rounded up). If centre is TRUE, the value from two moving averages (where k is rounded up and down respectively) are averaged, centering the moving average.

Value

Numerical time series object containing the simple moving average smoothed values.

Author(s)

Rob J Hyndman

See Also

decompose

Examples

```
plot(wineind)
sm <- ma(wineind,order=12)
lines(sm,col="red")
```

---

meanf *Mean Forecast*

Description

Returns forecasts and prediction intervals for an iid model applied to y.

Usage

```
meanf(y, h=10, level=c(80,95), fan=FALSE, lambda=NULL, biasadj=FALSE, x=y)
```

Arguments

y	a numeric vector or time series
h	Number of periods for forecasting
level	Confidence levels for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
x	Deprecated. Included for backwards compatibility.

Details

The iid model is

$$Y_t = \mu + Z_t$$

where Z_t is a normal iid error. Forecasts are given by

$$Y_n(h) = \mu$$

where μ is estimated by the sample mean.

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by meanf.

An object of class "forecast" is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either object itself or the time series used to create the model stored as object).
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

rwf

Examples

```
nile.fcast <- meanf(Nile, h=10)
plot(nile.fcast)
```

mforecast *Forecasting time series*

Description

mforecast is a class of objects for forecasting from multivariate time series or multivariate time series models. The function invokes particular *methods* which depend on the class of the first argument.

For example, the function forecast.mlm makes multivariate forecasts based on the results produced by tslm.

Usage

```
## S3 method for class 'mts'
forecast(object, h=ifelse(frequency(object)>1, 2*frequency(object), 10),
      level=c(80,95), fan=FALSE, robust=FALSE, lambda = NULL, find.frequency = FALSE,
        allow.multiplicative.trend=FALSE, ...)
```

Arguments

object	a multivariate time series or multivariate time series model for which forecasts are required
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.
robust	If TRUE, the function is robust to missing values and outliers in object. This argument is only valid when object is of class mts.
lambda	Box-Cox transformation parameter.
find.frequency	If TRUE, the function determines the appropriate period, if the data is of unknown period.
allow.multiplicative.trend	If TRUE, then ETS models with multiplicative trends are allowed. Otherwise, only additive or no trend ETS models are permitted.
...	Additional arguments affecting the forecasts produced.

Value

An object of class "mforecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the multivariate forecasts and prediction intervals.

The generic accessors functions fitted.values and residuals extract various useful features of the value returned by forecast$model.

An object of class "mforecast" is a list usually containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model. For models with additive errors, the residuals will be x minus the fitted values.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

See Also

Other functions which return objects of class `"mforecast"` are `forecast.mlm`, `forecast.varest`.

`monthdays` *Number of days in each season*

Description

Returns number of days in each month or quarter of the observed time period.

Usage

```
monthdays(x)
```

Arguments

`x`	time series

Details

Useful for month length adjustments

Value

Time series

Author(s)

Rob J Hyndman

See Also

bizdays

Examples

```
par(mfrow=c(2,1))
plot(ldeaths,xlab="Year",ylab="pounds",
    main="Monthly deaths from lung disease (UK)")
ldeaths.adj <- ldeaths/monthdays(ldeaths)*365.25/12
plot(ldeaths.adj,xlab="Year",ylab="pounds",
    main="Adjusted monthly deaths from lung disease (UK)")
```

---

msts *Multi-Seasonal Time Series*

Description

msts is an S3 class for multi seasonal time series objects, intended to be used for models that support multiple seasonal periods. The msts class inherits from the ts class and has an additional "msts" attribute which contains the vector of seasonal periods. All methods that work on a ts class, should also work on a msts class.

Usage

```
msts(data, seasonal.periods, ts.frequency=floor(max(seasonal.periods)),
    ... )
```

Arguments

`data`	A numeric vector, ts object, matrix or data frame. It is intended that the time series data is univariate, otherwise treated the same as ts().
`seasonal.periods`	A vector of the seasonal periods of the msts.
`ts.frequency`	The seasonal period that should be used as frequency of the underlying ts object. The default value is `max(seasonal.periods)`.
`...`	Arguments to be passed to the underlying call to `ts()`. For example `start=c(1987,5)`.

Value

An object of class `c("msts", "ts")`. If there is only one seasonal period (i.e., `length(seasonal.periods)==1`), then the object is of class `"ts"`.

Author(s)

Slava Razbash and Rob J Hyndman

Examples

```
x <- msts(taylor, seasonal.periods=c(48,336), start=2000+22/52)
y <- msts(USAccDeaths, seasonal.periods=12, start=1949)
```

---

na.interp *Interpolate missing values in a time series*

Description

Uses linear interpolation for non-seasonal series and a periodic stl decomposition with seasonal series to replace missing values.

Usage

```
na.interp(x, lambda = NULL)
```

Arguments

x	time series
lambda	a numeric value suggesting Box-cox transformation

Details

A more general and flexible approach is available using `na.approx` in the `zoo` package.

Value

Time series

Author(s)

Rob J Hyndman

See Also

`na.interp`, `tsoutliers`

Examples

```
data(gold)
plot(na.interp(gold))
```

`naive` *Naive and Random Walk Forecasts*

Description

`rwf()` returns forecasts and prediction intervals for a random walk with drift model applied to `y`. This is equivalent to an ARIMA(0,1,0) model with an optional drift coefficient. `naive()` is simply a wrapper to `rwf()` for simplicity. `snaive()` returns forecasts and prediction intervals from an ARIMA(0,0,0)(0,1,0)m model where m is the seasonal period.

Usage

```
naive(y, h=10, level=c(80,95), fan=FALSE, lambda=NULL, biasadj=FALSE, x=y)
rwf(y, h=10, drift=FALSE, level=c(80,95), fan=FALSE, lambda=NULL, biasadj=FALSE,x=y)
snaive(y, h=2*frequency(x), level=c(80,95), fan=FALSE, lambda=NULL, biasadj=FALSE,x=y)
```

Arguments

`y`	a numeric vector or time series
`h`	Number of periods for forecasting
`drift`	Logical flag. If TRUE, fits a random walk with drift model.
`level`	Confidence levels for prediction intervals.
`fan`	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`x`	Deprecated. Included for backwards compatibility.

Details

The random walk with drift model is

$$Y_t = c + Y_{t-1} + Z_t$$

where Z_t is a normal iid error. Forecasts are given by

$$Y_n(h) = ch + Y_n$$

. If there is no drift (as in `naive`), the drift parameter c=0. Forecast standard errors allow for uncertainty in estimating the drift parameter.

The seasonal naive model is

$$Y_t = Y_{t-m} + Z_t$$

where Z_t is a normal iid error.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `naive` or `snaive`.

An object of class `"forecast"` is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series
`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model. That is x minus fitted values.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

See Also

`Arima`

Examples

```
gold.fcast <- rwf(gold[1:60], h=50)
plot(gold.fcast)

plot(naive(gold,h=50),include=200)
plot(snaive(wineind))
```

`ndiffs` *Number of differences required for a stationary series*

Description

Functions to estimate the number of differences required to make a given time series stationary. `ndiffs` estimates the number of first differences and `nsdiffs` estimates the number of seasonal differences.

Usage

```
ndiffs(x, alpha=0.05, test=c("kpss","adf", "pp"), max.d=2)
nsdiffs(x, m=frequency(x), test=c("ocsb","ch"), max.D=1)
```

Arguments

`x`	A univariate time series
`alpha`	Level of the test
`m`	Length of seasonal period
`test`	Type of unit root test to use
`max.d`	Maximum number of non-seasonal differences allowed
`max.D`	Maximum number of seasonal differences allowed

Details

`ndiffs` uses a unit root test to determine the number of differences required for time series `x` to be made stationary. If `test="kpss"`, the KPSS test is used with the null hypothesis that `x` has a stationary root against a unit-root alternative. Then the test returns the least number of differences required to pass the test at the level `alpha`. If `test="adf"`, the Augmented Dickey-Fuller test is used and if `test="pp"` the Phillips-Perron test is used. In both of these cases, the null hypothesis is that `x` has a unit root against a stationary root alternative. Then the test returns the least number of differences required to fail the test at the level `alpha`.

`nsdiffs` uses seasonal unit root tests to determine the number of seasonal differences required for time series `x` to be made stationary (possibly with some lag-one differencing as well). If `test="ch"`, the Canova-Hansen (1995) test is used (with null hypothesis of deterministic seasonality) and if `test="ocsb"`, the Osborn-Chui-Smith-Birchenhall (1988) test is used (with null hypothesis that a seasonal unit root exists).

Value

An integer.

Author(s)

Rob J Hyndman and Slava Razbash

References

Canova F and Hansen BE (1995) "Are Seasonal Patterns Constant over Time? A Test for Seasonal Stability", *Journal of Business and Economic Statistics* **13**(3):237-252.

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See Also

auto.arima

Examples

```
ndiffs(WWWusage)
nsdiffs(log(AirPassengers))
ndiffs(diff(log(AirPassengers),12))
```

---

nnetar *Neural Network Time Series Forecasts*

Description

Feed-forward neural networks with a single hidden layer and lagged inputs for forecasting univariate time series.

Usage

```
nnetar(y, p, P=1, size, repeats=20, xreg=NULL, lambda=NULL, model=NULL,
    subset=NULL, scale.inputs=TRUE, x=y, ...)
```

Arguments

y	A numeric vector or time series.
p	Embedding dimension for non-seasonal time series. Number of non-seasonal lags used as inputs. For non-seasonal time series, the default is the optimal number of lags (according to the AIC) for a linear AR(p) model. For seasonal time series, the same method is used but applied to seasonally adjusted data (from an stl decomposition).
P	Number of seasonal lags used as inputs.
size	Number of nodes in the hidden layer. Default is half of the number of input nodes (including external regressors, if given) plus 1.
repeats	Number of networks to fit with different random starting weights. These are then averaged when producing forecasts.
xreg	Optionally, a vector or matrix of external regressors, which must have the same number of rows as `y`. Must be numeric.
lambda	Box-Cox transformation parameter.
model	Output from a previous call to `nnetar`. If model is passed, this same model is fitted to `y` without re-estimating any parameters.

subset	Optional vector specifying a subset of observations to be used in the fit. Can be an integer index vector or a logical vector the same length as y. All observations are used by default.
scale.inputs	If TRUE, inputs are scaled by subtracting the column means and dividing by their respective standard deviations. If lambda is not NULL, scaling is applied after Box-Cox transformation.
x	Deprecated. Included for backwards compatibility.
...	Other arguments passed to nnet for nnetar.

Details

A feed-forward neural network is fitted with lagged values of y as inputs and a single hidden layer with size nodes. The inputs are for lags 1 to p, and lags m to mP where m=frequency(y). If there are missing values in y or xreg), the corresponding rows (and any others which depend on them as lags) are omitted from the fit. A total of repeats networks are fitted, each with random starting weights. These are then averaged when computing forecasts. The network is trained for one-step forecasting. Multi-step forecasts are computed recursively.

For non-seasonal data, the fitted model is denoted as an NNAR(p,k) model, where k is the number of hidden nodes. This is analogous to an AR(p) model but with nonlinear functions. For seasonal data, the fitted model is called an NNAR(p,P,k)[m] model, which is analogous to an ARIMA(p,0,0)(P,0,0)[m] model but with nonlinear functions.

Value

Returns an object of class "nnetar".

The function summary is used to obtain and print a summary of the results.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by nnetar.

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
x	The original time series.
xreg	The external regressors used in fitting (if given).
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values (one-step forecasts)
...	Other arguments

Author(s)

Rob J Hyndman

Examples

```
fit <- nnetar(lynx)
fcast <- forecast(fit)
plot(fcast)

## Arguments can be passed to nnet()
fit <- nnetar(lynx, decay=0.5, maxit=150)
plot(forecast(fit))
lines(lynx)

## Fit model to first 100 years of lynx data
fit <- nnetar(window(lynx,end=1920), decay=0.5, maxit=150)
plot(forecast(fit,h=14))
lines(lynx)

## Apply fitted model to later data, including all optional arguments
fit2 <- nnetar(window(lynx,start=1921), model=fit)
```

`plot.Arima` *Plot characteristic roots from ARIMA model*

Description

Produces a plot of the inverse AR and MA roots of an ARIMA model. Inverse roots outside the unit circle are shown in red.

`autoplot` will produce an equivelant plot as a ggplot object.

Usage

```
## S3 method for class 'Arima'
plot(x, type=c("both","ar","ma"),
  main, xlab="Real", ylab="Imaginary", ...)
## S3 method for class 'Arima'
autoplot(object, type=c("both","ar","ma"), ...)
## S3 method for class 'ar'
plot(x, main, xlab="Real", ylab="Imaginary", ...)
## S3 method for class 'ar'
autoplot(object, ...)
```

Arguments

`x`	Object of class “Arima” or “ar”.
`object`	Object of class “Arima” or “ar”. Used for ggplot graphics (S3 method consistency).
`type`	Determines if both AR and MA roots are plotted, of if just one set is plotted.
`main`	Main title. Default is "Inverse AR roots" or "Inverse MA roots".

xlab	X-axis label.
ylab	Y-axis label.
...	Other plotting parameters passed to par.

Value

None. Function produces a plot

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

See Also

Arima, ar

Examples

```
library(ggplot2)

fit <- Arima(WWWusage, order=c(3,1,0))
plot(fit)
autoplot(fit)

fit <- Arima(woolyrnq,order=c(2,0,0),seasonal=c(2,1,1))
plot(fit)
autoplot(fit)

plot(ar.ols(gold[1:61]))
autoplot(ar.ols(gold[1:61]))
```

---

plot.bats *Plot components from BATS model*

Description

Produces a plot of the level, slope and seasonal components from a BATS or TBATS model.

Usage

```
## S3 method for class 'bats'
plot(x, main="Decomposition by BATS model", ...)
## S3 method for class 'tbats'
plot(x, main="Decomposition by TBATS model", ...)
```

Arguments

`x`	Object of class "ets".
`main`	Main title for plot.
`...`	Other plotting parameters passed to `par`.

Value

None. Function produces a plot

Author(s)

Rob J Hyndman

See Also

`bats`,`tbats`

Examples

```
## Not run:
fit <- tbats(USAccDeaths)
plot(fit)
## End(Not run)
```

`plot.ets` *Plot components from ETS model*

Description

Produces a plot of the level, slope and seasonal components from an ETS model.

`autoplot` will produce an equivelant plot as a ggplot object.

Usage

```
## S3 method for class 'ets'
plot(x, ...)
## S3 method for class 'ets'
autoplot(object, range.bars = NULL, ...)
```

Arguments

`x`	Object of class "ets".
`object`	Object of class "ets". Used for ggplot graphics (S3 method consistency).
`range.bars`	Logical indicating if each plot should have a bar at its right side representing relative size. If NULL, automatic selection takes place.
`...`	Other plotting parameters to affect the plot.

Value

None. Function produces a plot

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

See Also

ets

Examples

```
fit <- ets(USAccDeaths)
plot(fit)
plot(fit,plot.type="single",ylab="",col=1:3)

library(ggplot2)
autoplot(fit)
```

---

plot.forecast *Forecast plot*

Description

Plots historical data with forecasts and prediction intervals.

autoplot will produce a ggplot object.

Usage

```
## S3 method for class 'forecast'
plot(x, include, PI=TRUE, showgap=TRUE, shaded=TRUE,
    shadebars=(length(x$mean)<5), shadecols=NULL, col=1, fcol=4,
    pi.col=1, pi.lty=2, ylim=NULL, main=NULL, xlab="", ylab="", type="l",
    flty=1, flwd=2, ...)
## S3 method for class 'forecast'
autoplot(object, include, PI=TRUE,
    shadecols=c("#596DD5","#D5DBFF"), fcol="#0000AA", flwd=0.5, ...)
## S3 method for class 'forecast'
autolayer(object, series = NULL, PI = TRUE, showgap = TRUE, ...)
## S3 method for class 'splineforecast'
plot(x, fitcol=2, type="o", pch=19, ...)
## S3 method for class 'splineforecast'
autoplot(object, PI=TRUE, ...)
```

Arguments

`x`	Forecast object produced by `forecast`.
`object`	Forecast object produced by `forecast`. Used for ggplot graphics (S3 method consistency).
`include`	number of values from time series to include in plot. Default is all values.
`PI`	Logical flag indicating whether to plot prediction intervals.
`showgap`	If `showgap=FALSE`, the gap between the historical observations and the forecasts is removed.
`shaded`	Logical flag indicating whether prediction intervals should be shaded (`TRUE`) or lines (`FALSE`)
`shadebars`	Logical flag indicating if prediction intervals should be plotted as shaded bars (if `TRUE`) or a shaded polygon (if `FALSE`). Ignored if `shaded=FALSE`. Bars are plotted by default if there are fewer than five forecast horizons.
`shadecols`	Colors for shaded prediction intervals. To get default colors used prior to v3.26, set `shadecols="oldstyle"`.
`col`	Colour for the data line.
`fcol`	Colour for the forecast line.
`flty`	Line type for the forecast line.
`flwd`	Line width for the forecast line.
`pi.col`	If `shaded=FALSE` and `PI=TRUE`, the prediction intervals are plotted in this colour.
`pi.lty`	If `shaded=FALSE` and `PI=TRUE`, the prediction intervals are plotted using this line type.
`ylim`	Limits on y-axis.
`main`	Main title.
`xlab`	X-axis label.
`ylab`	Y-axis label.
`series`	Matches an unidentified forecast layer with a coloured object on the plot.
`fitcol`	Line colour for fitted values.
`type`	1-character string giving the type of plot desired. As for `plot.default`.
`pch`	Plotting character (if `type=="p"` or `type=="o"`).
`...`	Other plotting parameters to affect the plot.

Value

None.

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

References

Hyndman and Athanasopoulos (2014) *Forecasting: principles and practice*, OTexts: Melbourne, Australia. http://www.otexts.org/fpp/

See Also

plot.ts

Examples

```
library(ggplot2)

wine.fit <- hw(wineind,h=48)
plot(wine.fit)
autoplot(wine.fit)

fit <- tslm(wineind ~ fourier(wineind,4))
fcast <- forecast(fit, newdata=data.frame(fourier(wineind,4,20)))
autoplot(fcast)

fcast <- splinef(airmiles,h=5)
plot(fcast)
autoplot(fcast)
```

---

plot.mforecast — *Multivariate forecast plot*

Description

Plots historical data with multivariate forecasts and prediction intervals.

autoplot will produce an equivelant plot as a ggplot object.

Usage

```
## S3 method for class 'mforecast'
plot(x, main=paste("Forecasts from",unique(x$method)),xlab="time",...)
## S3 method for class 'mforecast'
autoplot(object, PI = TRUE, facets = TRUE, colour = FALSE, ...)
## S3 method for class 'mforecast'
autolayer(object, series = NULL, PI = TRUE, ...)
```

Arguments

x	Multivariate forecast object of class mforecast.
object	Multivariate forecast object of class mforecast. Used for ggplot graphics (S3 method consistency).

`main`	Main title. Default is the forecast method. For autoplot, specify a vector of titles for each plot.
`xlab`	X-axis label. For autoplot, specify a vector of labels for each plot.
`PI`	If `FALSE`, confidence intervals will not be plotted, giving only the forecast line.
`facets`	If TRUE, multiple time series will be faceted. If FALSE, each series will be assigned a colour.
`colour`	If TRUE, the time series will be assigned a colour aesthetic
`series`	Matches an unidentified forecast layer with a coloured object on the plot.
`...`	additional arguments to each individual `plot`.

Author(s)

Mitchell O'Hara-Wild

References

Hyndman and Athanasopoulos (2014) *Forecasting: principles and practice*, OTexts: Melbourne, Australia. http://www.otexts.org/fpp/

See Also

`plot.forecast`, `plot.ts`

Examples

```
library(ggplot2)

lungDeaths <- cbind(mdeaths, fdeaths)
fit <- tslm(lungDeaths ~ trend + season)
fcast <- forecast(fit, h=10)
plot(fcast)
autoplot(fcast)

carPower <- as.matrix(mtcars[,c("qsec","hp")])
carmpg <- mtcars[,"mpg"]
fit <- lm(carPower ~ carmpg)
fcast <- forecast(fit, newdata=data.frame(carmpg=30))
plot(fcast, xlab="Year")
autoplot(fcast, xlab=rep("Year",2))
```

residuals.Arima *Residuals for various time series models*

Description

Returns time series of residuals from a fitted model.

Usage

```
## S3 method for class 'ar'
residuals(object, type=c("innovation","response"),...)
## S3 method for class 'Arima'
residuals(object, type=c("innovation","response","regression"), h=1, ...)
## S3 method for class 'bats'
residuals(object, type=c("innovation","response"), h=1, ...)
## S3 method for class 'ets'
residuals(object, type=c("innovation","response"), h=1, ...)
## S3 method for class 'forecast'
residuals(object, type=c("innovation","response"), ...)
## S3 method for class 'fracdiff'
residuals(object, type=c("innovation","response"), ...)
## S3 method for class 'nnetar'
residuals(object, type=c("innovation","response"), h=1, ...)
## S3 method for class 'stlm'
residuals(object, type=c("innovation","response"), ...)
arima.errors(object)
```

Arguments

`object`	An object containing a time series model of class `ar`, `Arima`, `bats`, `ets`, `fracdiff`, `nnetar` or `stlm`. If object is of class `forecast`,
`type`	Type of residual.
`h`	If `type='response'`, then the fitted values are computed for `h`-step forecasts.
`...`	Other arguments not used.

Details

Innovation residuals correspond to the white noise process that drives the evolution of the time series model. Response residuals are the difference between the observations and the fitted values (equivalent to `h`-step forecasts). For functions with no `h` argument, `h=1`. For homoscedastic models, the innovation residuals and the response residuals for `h=1` are identical. Regression residuals are available for regression models with ARIMA errors, and are equal to the original data minus the effect of the regression variables. If there are no regression variables, the errors will be identical to the original series (possibly adjusted to have zero mean). `arima.errors` is a deprecated function which is identical to `residuals.Arima(object, type="regression")`.

Value

A ts object

Author(s)

Rob J Hyndman

See Also

fitted.Arima, checkresiduals.

Examples

```
fit <- Arima(lynx,order=c(4,0,0), lambda=0.5)

plot(residuals(fit))
plot(residuals(fit, type='response'))
```

---

seasadj *Seasonal adjustment*

Description

Returns seasonally adjusted data constructed by removing the seasonal component.

Usage

```
seasadj(object, ...)
```

Arguments

object	Object created by decompose, stl or tbats.
...	Other arguments not currently used.

Value

Univariate time series.

Author(s)

Rob J Hyndman

See Also

stl, decompose, tbats.

Examples

```
plot(AirPassengers)
lines(seasadj(decompose(AirPassengers,"multiplicative")),col=4)
```

`seasonal` *Extract components from a time series decomposition*

Description

Returns a univariate time series equal to either a seasonal component, trend-cycle component or remainder component from a time series decomposition.

Usage

```
seasonal(object)
trendcycle(object)
remainder(object)
```

Arguments

`object`	Object created by `decompose`, `stl` or `tbats`.

Value

Univariate time series.

Author(s)

Rob J Hyndman

See Also

`stl`, `decompose`, `tbats`, `seasadj`.

Examples

```
plot(USAccDeaths)
fit <- stl(USAccDeaths, s.window="periodic")
lines(trendcycle(fit),col="red")

library(ggplot2)
autoplot(cbind(
    Data=USAccDeaths,
    Seasonal=seasonal(fit),
     Trend=trendcycle(fit),
    Remainder=remainder(fit)),
    facets=TRUE) +
  ylab("") + xlab("Year")
```

seasonaldummy *Seasonal dummy variables*

Description

`seasonaldummy` returns a matrix of dummy variables suitable for use in `Arima`, `auto.arima` or `tslm`. The last season is omitted and used as the control.

`seasonaldummyf` is deprecated, instead use the `h` argument in `seasonaldummy`.

Usage

```
seasonaldummy(x,h)
```

Arguments

x	Seasonal time series: a `ts` or a `msts` object
h	Number of periods ahead to forecast (optional)

Details

The number of dummy variables is determined from the time series characteristics of `x`. When `h` is missing, the length of `x` also determines the number of rows for the matrix returned by `seasonaldummy`. the value of `h` determines the number of rows for the matrix returned by `seasonaldummy`, typically used for forecasting. The values within `x` are not used.

Value

Numerical matrix.

Author(s)

Rob J Hyndman

See Also

`fourier`

Examples

```
plot(ldeaths)

# Using seasonal dummy variables
month <- seasonaldummy(ldeaths)
deaths.lm  <- tslm(ldeaths ~ month)
tsdisplay(residuals(deaths.lm))
ldeaths.fcast <- forecast(deaths.lm,
    data.frame(month=I(seasonaldummy(ldeaths,36))))
plot(ldeaths.fcast)
```

```
# A simpler approach to seasonal dummy variables
deaths.lm  <- tslm(ldeaths ~ season)
ldeaths.fcast <- forecast(deaths.lm, h=36)
plot(ldeaths.fcast)
```

---

seasonplot *Seasonal plot*

Description

Plots a seasonal plot as described in Hyndman and Athanasopoulos (2014, chapter 2). This is like a time plot except that the data are plotted against the seasons in separate years.

Usage

```
seasonplot(x, s, season.labels=NULL, year.labels=FALSE,
    year.labels.left=FALSE, type="o", main, xlab=NULL, ylab="",
    col=1, labelgap=0.1, ...)

ggseasonplot(x, year.labels=FALSE, year.labels.left=FALSE,
    type=NULL, col=NULL, continuous=FALSE, polar=FALSE,
    labelgap=0.04, ...)
```

Arguments

`x`	a numeric vector or time series.
`s`	seasonal frequency of x
`season.labels`	Labels for each season in the "year"
`year.labels`	Logical flag indicating whether labels for each year of data should be plotted on the right.
`year.labels.left`	Logical flag indicating whether labels for each year of data should be plotted on the left.
`type`	plot type (as for `plot`). Not yet supported for ggseasonplot.
`main`	Main title.
`xlab`	X-axis label.
`ylab`	Y-axis label.
`col`	Colour
`continuous`	Should the colour scheme for years be continuous or discrete?
`polar`	Plot the graph on seasonal coordinates
`labelgap`	Distance between year labels and plotted lines
`...`	additional arguments to `plot`.

Value

None.

Author(s)

Rob J Hyndman & Mitchell O'Hara-Wild

References

Hyndman and Athanasopoulos (2014) *Forecasting: principles and practice*, OTexts: Melbourne, Australia. http://www.otexts.org/fpp/

See Also

monthplot

Examples

```
seasonplot(AirPassengers, col=rainbow(12), year.labels=TRUE)
ggseasonplot(AirPassengers, col=rainbow(12), year.labels=TRUE)
ggseasonplot(AirPassengers, year.labels=TRUE, continuous=TRUE)
```

---

ses *Exponential smoothing forecasts*

Description

Returns forecasts and other information for exponential smoothing forecasts applied to y.

Usage

```
ses(y, h=10, level=c(80,95), fan=FALSE,
    initial=c("optimal","simple"), alpha=NULL,
    lambda=NULL, biasadj=FALSE, x=y, ...)
holt(y, h=10, damped=FALSE, level=c(80,95), fan=FALSE,
    initial=c("optimal","simple"), exponential=FALSE,
    alpha=NULL, beta=NULL, phi=NULL, lambda=NULL, biasadj=FALSE, x=y, ...)
hw(y, h=2*frequency(x), seasonal=c("additive","multiplicative"),
    damped=FALSE, level=c(80,95), fan=FALSE,
    initial=c("optimal","simple"), exponential=FALSE,
    alpha=NULL, beta=NULL, gamma=NULL, phi=NULL,
    lambda=NULL, biasadj=FALSE, x=y, ...)
```

Arguments

`y`	a numeric vector or time series
`h`	Number of periods for forecasting.
`damped`	If TRUE, use a damped trend.
`seasonal`	Type of seasonality in `hw` model. "additive" or "multiplicative"
`level`	Confidence level for prediction intervals.
`fan`	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
`initial`	Method used for selecting initial state values. If `optimal`, the initial values are optimized along with the smoothing parameters using `ets`. If `simple`, the initial values are set to values obtained using simple calculations on the first few observations. See Hyndman & Athanasopoulos (2014) for details.
`exponential`	If TRUE, an exponential trend is fitted. Otherwise, the trend is (locally) linear.
`alpha`	Value of smoothing parameter for the level. If `NULL`, it will be estimated.
`beta`	Value of smoothing parameter for the trend. If `NULL`, it will be estimated.
`gamma`	Value of smoothing parameter for the seasonal component. If `NULL`, it will be estimated.
`phi`	Value of damping parameter if `damped=TRUE`. If `NULL`, it will be estimated.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated. When `lambda=TRUE`, `additive.only` is set to FALSE.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`x`	Deprecated. Included for backwards compatibility.
`...`	Other arguments passed to `forecast.ets`.

Details

ses, holt and hw are simply convenient wrapper functions for `forecast(ets(...))`.

Value

An object of class `"forecast"`.

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `ets` and associated functions.

An object of class `"forecast"` is a list containing at least the following elements:

`model`	A list containing information about the fitted model
`method`	The name of the forecasting method as a character string
`mean`	Point forecasts as a time series

`lower`	Lower limits for prediction intervals
`upper`	Upper limits for prediction intervals
`level`	The confidence values associated with the prediction intervals
`x`	The original time series (either `object` itself or the time series used to create the model stored as `object`).
`residuals`	Residuals from the fitted model.
`fitted`	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

References

Hyndman, R.J., Koehler, A.B., Ord, J.K., Snyder, R.D. (2008) *Forecasting with exponential smoothing: the state space approach*, Springer-Verlag: New York. `http://www.exponentialsmoothing.net`.

Hyndman, R.J., Athanasopoulos (2014) *Forecasting: principles and practice*, OTexts: Melbourne, Australia. `http://www.otexts.org/fpp`.

See Also

`ets`, `HoltWinters`, `rwf`, `arima`.

Examples

```
fcast <- holt(airmiles)
plot(fcast)
deaths.fcast <- hw(USAccDeaths,h=48)
plot(deaths.fcast)
```

`simulate.ets` *Simulation from a time series model*

Description

Returns a time series based on the model object `object`.

Usage

```
## S3 method for class 'ets'
simulate(object, nsim=length(object$x), seed=NULL, future=TRUE,
    bootstrap=FALSE, innov=NULL, ...)
## S3 method for class 'ar'
simulate(object, nsim=object$n.used, seed=NULL, future=TRUE,
    bootstrap=FALSE,  innov=NULL, ...)
```

```
## S3 method for class 'Arima'
simulate(object, nsim=length(object$x), seed=NULL, xreg=NULL, future=TRUE,
    bootstrap=FALSE,  innov=NULL, lambda=object$lambda, ...)
## S3 method for class 'fracdiff'
simulate(object, nsim=object$n, seed=NULL, future=TRUE,
    bootstrap=FALSE,  innov=NULL, ...)
## S3 method for class 'nnetar'
simulate(object, nsim=length(object$x), seed=NULL, xreg=NULL, future=TRUE,
    bootstrap=FALSE,  innov=NULL, lambda=object$lambda, ...)
```

Arguments

`object`	An object of class "ets", "Arima", "ar" or "nnetar".
`nsim`	Number of periods for the simulated series. Ignored if either `xreg` or `innov` are not `NULL`.
`seed`	Either `NULL` or an integer that will be used in a call to `set.seed` before simulating the time series. The default, `NULL`, will not change the random generator state.
`future`	Produce sample paths that are future to and conditional on the data in `object`. Otherwise simulate unconditionally.
`bootstrap`	Do simulation using resampled errors rather than normally distributed errors or errors provided as `innov`.
`innov`	A vector of innovations to use as the error series. Ignored if `bootstrap==TRUE`. If not `NULL`, the value of `nsim` is set to length of `innov`.
`xreg`	New values of `xreg` to be used for forecasting. The value of `nsim` is set to the number of rows of `xreg` if it is not `NULL`.
`lambda`	Box-Cox parameter. If not `NULL`, the simulated series is transformed using an inverse Box-Cox transformation with parameter `lamda`.
`...`	Other arguments, not currently used.

Details

With `simulate.Arima()`, the `object` should be produced by `Arima` or `auto.arima`, rather than `arima`. By default, the error series is assumed normally distributed and generated using `rnorm`. If `innov` is present, it is used instead. If `bootstrap=TRUE` and `innov=NULL`, the residuals are resampled instead.

When `future=TRUE`, the sample paths are conditional on the data. When `future=FALSE` and the model is stationary, the sample paths do not depend on the data at all. When `future=FALSE` and the model is non-stationary, the location of the sample paths is arbitrary, so they all start at the value of the first observation.

Value

An object of class "ts".

Author(s)

Rob J Hyndman

See Also

ets, Arima, auto.arima, ar, arfima, nnetar.

Examples

```
fit <- ets(USAccDeaths)
plot(USAccDeaths, xlim=c(1973,1982))
lines(simulate(fit, 36), col="red")
```

---

sindexf *Forecast seasonal index*

Description

Returns vector containing the seasonal index for h future periods. If the seasonal index is non-periodic, it uses the last values of the index.

Usage

```
sindexf(object, h)
```

Arguments

object	Output from decompose or stl.
h	Number of periods ahead to forecast

Value

Time series

Author(s)

Rob J Hyndman

Examples

```
uk.stl <- stl(UKDriverDeaths,"periodic")
uk.sa <- seasadj(uk.stl)
uk.fcast <- holt(uk.sa,36)
seasf <- sindexf(uk.stl,36)
uk.fcast$mean <- uk.fcast$mean + seasf
uk.fcast$lower <- uk.fcast$lower + cbind(seasf,seasf)
uk.fcast$upper <- uk.fcast$upper + cbind(seasf,seasf)
uk.fcast$x <- UKDriverDeaths
plot(uk.fcast,main="Forecasts from Holt's method with seasonal adjustment")
```

`splinef` *Cubic Spline Forecast*

Description

Returns local linear forecasts and prediction intervals using cubic smoothing splines.

Usage

```
splinef(y, h=10, level=c(80,95), fan=FALSE, lambda=NULL, biasadj=FALSE,
    method=c("gcv","mle"), x=y)
```

Arguments

`y`	a numeric vector or time series
`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.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, forecasts back-transformed via an inverse Box-Cox transformation.
`biasadj`	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
`method`	Method for selecting the smoothing parameter. If `method="gcv"`, the generalized cross-validation method from `smooth.spline` is used. If `method="mle"`, the maximum likelihood method from Hyndman et al (2002) is used.
`x`	Deprecated. Included for backwards compatibility.

Details

The cubic smoothing spline model is equivalent to an ARIMA(0,2,2) model but with a restricted parameter space. The advantage of the spline model over the full ARIMA model is that it provides a smooth historical trend as well as a linear forecast function. Hyndman, King, Pitrun, and Billah (2002) show that the forecast performance of the method is hardly affected by the restricted parameter space.

Value

An object of class "`forecast`".

The function `summary` is used to obtain and print a summary of the results, while the function `plot` produces a plot of the forecasts and prediction intervals.

The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `splinef`.

An object of class `"forecast"` containing the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either `object` itself or the time series used to create the model stored as `object`).
onestepf	One-step forecasts from the fitted model.
fitted	Smooth estimates of the fitted trend using all data.
residuals	Residuals from the fitted model. That is x minus one-step forecasts.

Author(s)

Rob J Hyndman

References

Hyndman, King, Pitrun and Billah (2005) Local linear forecasts using cubic smoothing splines. *Australian and New Zealand Journal of Statistics*, **47**(1), 87-99. http://robjhyndman.com/papers/splinefcast/.

See Also

`smooth.spline`, `arima`, `holt`.

Examples

```
fcast <- splinef(uspop,h=5)
plot(fcast)
summary(fcast)
```

`subset.ts` *Subsetting a time series*

Description

Various types of subsetting of a time series. Allows subsetting by index values (unlike `window`). Also allows extraction of the values of a specific season or subset of seasons in each year. For example, to extract all values for the month of May from a time series.

Usage

```
## S3 method for class 'ts'
subset(x, subset=NULL, month=NULL, quarter=NULL, season=NULL,
  start=NULL, end=NULL, ...)
```

Arguments

x	a univariate time series to be subsetted
subset	optional logical expression indicating elements to keep; missing values are taken as false. subset must be the same length as x.
month	Numeric or character vector of months to retain. Partial matching on month names used.
quarter	Numeric or character vector of quarters to retain.
season	Numeric vector of seasons to retain.
start	Index of start of contiguous subset.
end	Index of end of contiguous subset.
...	Other arguments, unused.

Details

If character values for months are used, either upper or lower case may be used, and partial unambiguous names are acceptable. Possible character values for quarters are "Q1", "Q2", "Q3", and "Q4".

Value

If subset is used, a numeric vector is returned with no ts attributes. If start and/or end are used, a ts object is returned consisting of x[start:end], with the appropriate time series attributes retained. Otherwise, a ts object is returned with frequency equal to the length of month, quarter or season.

Author(s)

Rob J Hyndman

See Also

subset, window

Examples

```
plot(subset(gas,month="November"))
subset(woolyrnq,quarter=3)
subset(USAccDeaths, start=49)
```

`taylor` *Half-hourly electricity demand*

Description

Half-hourly electricity demand in England and Wales from Monday 5 June 2000 to Sunday 27 August 2000. Discussed in Taylor (2003), and kindly provided by James W Taylor.

Usage

```
taylor
```

Format

Time series data

Source

James W Taylor

References

Taylor, J.W. (2003) Short-term electricity demand forecasting using double seasonal exponential smoothing. *Journal of the Operational Research Society*, **54**, 799-805.

Examples

```
plot(taylor)
```

`tbats` *TBATS model (Exponential smoothing state space model with Box-Cox transformation, ARMA errors, Trend and Seasonal components)*

Description

Fits a TBATS model applied to `y`, as described in De Livera, Hyndman & Snyder (2011). Parallel processing is used by default to speed up the computations.

Usage

```
tbats(y, use.box.cox=NULL, use.trend=NULL, use.damped.trend=NULL,
    seasonal.periods=NULL, use.arma.errors=TRUE, use.parallel=length(y)>1000,
    num.cores=2, bc.lower=0, bc.upper=1, biasadj=FALSE, model=NULL, ...)
```

Arguments

- `y` — The time series to be forecast. Can be `numeric`, `msts` or `ts`. Only univariate time series are supported.
- `use.box.cox` — `TRUE/FALSE` indicates whether to use the Box-Cox transformation or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `use.trend` — `TRUE/FALSE` indicates whether to include a trend or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `use.damped.trend` — `TRUE/FALSE` indicates whether to include a damping parameter in the trend or not. If `NULL` then both are tried and the best fit is selected by AIC.
- `seasonal.periods` — If `y` is `numeric` then seasonal periods can be specified with this parameter.
- `use.arma.errors` — `TRUE/FALSE` indicates whether to include ARMA errors or not. If `TRUE` the best fit is selected by AIC. If `FALSE` then the selection algorithm does not consider ARMA errors.
- `use.parallel` — `TRUE/FALSE` indicates whether or not to use parallel processing.
- `num.cores` — The number of parallel processes to be used if using parallel processing. If `NULL` then the number of logical cores is detected and all available cores are used.
- `bc.lower` — The lower limit (inclusive) for the Box-Cox transformation.
- `bc.upper` — The upper limit (inclusive) for the Box-Cox transformation.
- `biasadj` — Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
- `model` — Output from a previous call to `tbats`. If model is passed, this same model is fitted to `y` without re-estimating any parameters.
- `...` — Additional arguments to be passed to `auto.arima` when choose an ARMA(p, q) model for the errors. (Note that xreg will be ignored, as will any arguments concerning seasonality and differencing, but arguments controlling the values of p and q will be used.)

Value

An object with class `c("tbats", "bats")`. The generic accessor functions `fitted.values` and `residuals` extract useful features of the value returned by `bats` and associated functions. The fitted model is designated TBATS(omega, p,q, phi, <m1,k1>,...,<mJ,kJ>) where omega is the Box-Cox parameter and phi is the damping parameter; the error is modelled as an ARMA(p,q) process and m1,...,mJ list the seasonal periods used in the model and k1,...,kJ are the corresponding number of Fourier terms used for each seasonality.

Author(s)

Slava Razbash and Rob J Hyndman

References

De Livera, A.M., Hyndman, R.J., & Snyder, R. D. (2011), Forecasting time series with complex seasonal patterns using exponential smoothing, *Journal of the American Statistical Association*, **106**(496), 1513-1527.

See Also

`tbats.components`.

Examples

```
## Not run:
fit <- tbats(USAccDeaths)
plot(forecast(fit))

taylor.fit <- tbats(taylor)
plot(forecast(taylor.fit))
## End(Not run)
```

---

tbats.components — *Extract components of a TBATS model*

Description

Extract the level, slope and seasonal components of a TBATS model.

Usage

```
tbats.components(x)
```

Arguments

x	A tbats object created by `tbats`.

Value

A multiple time series (`mts`) object.

Author(s)

Slava Razbash and Rob J Hyndman

References

De Livera, A.M., Hyndman, R.J., & Snyder, R. D. (2011), Forecasting time series with complex seasonal patterns using exponential smoothing, *Journal of the American Statistical Association*, **106**(496), 1513-1527.

See Also

tbats.

Examples

```
## Not run:
fit <- tbats(USAccDeaths, use.parallel=FALSE)
components <- tbats.components(fit)
plot(components)
## End(Not run)
```

---

thetaf *Theta method forecast*

Description

Returns forecasts and prediction intervals for a theta method forecast.

Usage

```
thetaf(y, h=ifelse(frequency(y)>1, 2*frequency(y), 10),
  level=c(80,95), fan=FALSE, x=y)
```

Arguments

y	a numeric vector or time series
h	Number of periods for forecasting
level	Confidence levels for prediction intervals.
fan	If TRUE, level is set to seq(51,99,by=3). This is suitable for fan plots.
x	Deprecated. Included for backwards compatibility.

Details

The theta method of Assimakopoulos and Nikolopoulos (2000) is equivalent to simple exponential smoothing with drift. This is demonstrated in Hyndman and Billah (2003).

The series is tested for seasonality using the test outlined in A&N. If deemed seasonal, the series is seasonally adjusted using a classical multiplicative decomposition before applying the theta method. The resulting forecasts are then reseasonalized.

Prediction intervals are computed using the underlying state space model.

More general theta methods are available in the forecTheta package.

Value

An object of class "forecast".

The function summary is used to obtain and print a summary of the results, while the function plot produces a plot of the forecasts and prediction intervals.

The generic accessor functions fitted.values and residuals extract useful features of the value returned by rwf.

An object of class "forecast" is a list containing at least the following elements:

model	A list containing information about the fitted model
method	The name of the forecasting method as a character string
mean	Point forecasts as a time series
lower	Lower limits for prediction intervals
upper	Upper limits for prediction intervals
level	The confidence values associated with the prediction intervals
x	The original time series (either object itself or the time series used to create the model stored as object).
residuals	Residuals from the fitted model. That is x minus fitted values.
fitted	Fitted values (one-step forecasts)

Author(s)

Rob J Hyndman

References

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

Hyndman, R.J., and Billah, B. (2003) Unmasking the Theta method. *International J. Forecasting*, **19**, 287-290.

See Also

arima, meanf, rwf, ses

Examples

```
nile.fcast <- thetaf(Nile)
plot(nile.fcast)
```

tsclean *Identify and replace outliers and missing values in a time series*

Description

Uses supsmu for non-seasonal series and a periodic stl decompostion with seasonal series to identify outliers. To estimate missing values and outlier replacements, linear interpolation is used on the (possibly seasonally adjusted) series

Usage

```
tsclean(x, replace.missing = TRUE, lambda = NULL)
```

Arguments

x	time series
replace.missing	If TRUE, it not only replaces outliers, but also interpolates missing values
lambda	a numeric value giving the Box-Cox transformation parameter

Value

Time series

Author(s)

Rob J Hyndman

See Also

na.interp, tsoutliers, supsmu

Examples

```
cleangold <- tsclean(gold)
```

`tsCV` *Time series cross-validation*

Description

`tsCV` computes the forecast errors obtained by applying `forecastfunction` to subsets of the time series `y` using a rolling forecast origin.

Usage

```
tsCV(y, forecastfunction, h=1, ...)
```

Arguments

`y` Univariate time series

`forecastfunction` Function to return an object of class `forecast`. Its first argument must be a univariate time series, and it must have an argument `h` for the forecast horizon.

`h` Forecast horizon

`...` Other arguments are passed to `forecastfunction`.

Details

Let `y` contain the time series $y_1, \dots, y_T$. Then `forecastfunction` is applied successively to the time series $y_1, \dots, y_t$, for $t = 1, \dots, T - h$, making predictions $\hat{y}_{t+h|t}$. The errors are given by $e_{t+h} = y_{t+h} - \hat{y}_{t+h|t}$. These are returned as a vector, $e_1, \dots, e_T$. The first few errors may be missing as it may not be possible to apply `forecastfunction` to very short time series.

Value

Numerical time series object containing the forecast errors.

Author(s)

Rob J Hyndman

See Also

CV, CVar, residuals.Arima.

Examples

```
#Fit an AR(2) model to each subset
far2 <- function(x, h){forecast(Arima(x, order=c(2,0,0)), h=h)}
e <- tsCV(lynx, far2, h=1)
```

tsdisplay *Time series display*

Description

Plots a time series along with its acf and either its pacf, lagged scatterplot or spectrum.

ggtsdisplay will produce the equivelant plot using ggplot graphics.

Usage

```
tsdisplay(x, plot.type=c("partial","histogram","scatter","spectrum"),
    points=TRUE, ci.type=c("white", "ma"),
    lag.max, na.action=na.contiguous,
    main=NULL, xlab="", ylab="", pch=1, cex=0.5, ...)

ggtsdisplay(x, plot.type=c("partial","histogram","scatter","spectrum"),
   points=TRUE, smooth=FALSE, lag.max, na.action=na.contiguous, theme=NULL, ...)
```

Arguments

x	a numeric vector or time series.
plot.type	type of plot to include in lower right corner.
points	logical flag indicating whether to show the individual points or not in the time plot.
smooth	logical flag indicating whether to show a smooth loess curve superimposed on the time plot.
ci.type	type of confidence limits for ACF that is passed to acf. Should the confidence limits assume a white noise input or for lag k an MA($k-1$) input?
lag.max	the maximum lag to plot for the acf and pacf. A suitable value is selected by default if the argument is missing.
na.action	function to handle missing values in acf, pacf and spectrum calculations. The default is na.contiguous. Useful alternatives are na.pass and na.interp.
theme	Adds a ggplot element to each plot, typically a theme.
main	Main title.
xlab	X-axis label.
ylab	Y-axis label.
pch	Plotting character.
cex	Character size.
...	additional arguments to acf.

Value

None.

Author(s)

Rob J Hyndman

References

Hyndman and Athanasopoulos (2014) *Forecasting: principles and practice*, OTexts: Melbourne, Australia. http://www.otexts.org/fpp/

See Also

plot.ts, Acf, spec.ar

Examples

```
tsdisplay(diff(WWWusage))
ggtsdisplay(USAccDeaths, plot.type="scatter")

library(ggplot2)
ggtsdisplay(USAccDeaths, plot.type="scatter", theme=theme_bw())
```

---

tslm *Fit a linear model with time series components*

Description

tslm is used to fit linear models to time series including trend and seasonality components.

Usage

```
tslm(formula, data, subset, lambda=NULL, biasadj=FALSE, ...)
```

Arguments

formula	an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.
data	an optional data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which lm is called.
subset	an optional subset containing rows of data to keep. For best results, pass a logical vector of rows to keep. Also supports subset() functions.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data are transformed via a Box-Cox transformation.
biasadj	Use adjusted back-transformed mean for Box-Cox transformations. If TRUE, point forecasts and fitted values are mean forecast. Otherwise, these points can be considered the median of the forecast densities.
...	Other arguments passed to lm().

Details

tslm is largely a wrapper for lm() except that it allows variables "trend" and "season" which are created on the fly from the time series characteristics of the data. The variable "trend" is a simple time trend and "season" is a factor indicating the season (e.g., the month or the quarter depending on the frequency of the data).

Value

Returns an object of class "lm".

Author(s)

Mitchell O'Hara-Wild and Rob J Hyndman

See Also

forecast.lm, lm.

Examples

```
y <- ts(rnorm(120,0,3) + 1:120 + 20*sin(2*pi*(1:120)/12), frequency=12)
fit <- tslm(y ~ trend + season)
plot(forecast(fit, h=20))
```

---

tsoutliers — *Identify and replace outliers in a time series*

Description

Uses supsmu for non-seasonal series and a periodic stl decompostion with seasonal series to identify outliers and estimate their replacements.

Usage

```
tsoutliers(x, iterate = 2, lambda = NULL)
```

Arguments

x	time series
iterate	the number of iteration only for non-seasonal series
lambda	Allowing Box-cox transformation

Value

index	Indicating the index of outlier(s)
replacement	Suggested numeric values to replace identified outliers

Author(s)

Rob J Hyndman

See Also

na.interp, tsclean

Examples

```
data(gold)
tsoutliers(gold)
```

---

wineind *Australian total wine sales*

Description

Australian total wine sales by wine makers in bottles <= 1 litre. Jan 1980 – Aug 1994.

Usage

```
wineind
```

Format

Time series data

Source

Time Series Data Library. http://data.is/TSDLdemo

Examples

```
tsdisplay(wineind)
```

woolyrnq *Quarterly production of woollen yarn in Australia*

Description

Quarterly production of woollen yarn in Australia: tonnes. Mar 1965 – Sep 1994.

Usage

```
woolyrnq
```

Format

Time series data

Source

Time Series Data Library. http://data.is/TSDLdemo

Examples

```
tsdisplay(woolyrnq)
```

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