Package ‘forecast’

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Version 6.2

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), stats, graphics, zoo, timeDate

Imports tseries, fracdiff, Rcpp (>= 0.11.0), nnet, colorspace, parallel

Suggests testthat, fpp

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

LazyData yes

ByteCompile TRUE

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

License GPL (>= 2)

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

NeedsCompilation yes

Repository CRAN

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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 Function Estimation*

Description

The function Acf computes (and by default plots) an estimate of the autocorrelation function of a univariate time series. Function Pacf computes (and by default plots) an estimate of the partial autocorrelation function of a univariate time series.

Usage

```
Acf(x, lag.max=NULL, type=c("correlation", "partial"),
   plot=TRUE, main=NULL, xlim=NULL, ylim=NULL, xlab="Lag", ylab=NULL,
   na.action=na.contiguous, ...)
Pacf(x, main=NULL, ...)
taperedacf(x, lag.max=NULL, type=c("correlation", "partial"),
   plot=TRUE, calc.ci=TRUE, level=95, nsim=100,
   xlim=NULL, ylim=NULL, xlab="Lag",  ylab=NULL, ...)
taperedpacf(x, ...)
```

Arguments

x	a univariate time series
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) or "partial".
plot	logical. If TRUE (the default) the acf is plotted.
main	Title for plot
xlim	The x limits of the plot
ylim	The y limits of the plot
xlab	The label on the x-axis of the plot
ylab	The label on the y-axis of the plot
na.action	function to handle missing values. Default is na.contiguous. Useful alternatives are na.pass and na.interp.
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 acf or to the plotting function.

Details

The functions improve the acf and pacf functions when applied to univariate time series. The main differences are that Acf does not plot a spike at lag 0 (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 and Pacf 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, 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(x, drange=c(0, 0.5), estim=c("mle","ls"), lambda=NULL, ...)
```

Arguments

`x`	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.
`lambda`	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data transformed before model is estimated.
`...`	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 `x`.

Usage

```
Arima(x, order=c(0,0,0), seasonal=c(0,0,0),
    xreg=NULL, include.mean=TRUE, include.drift=FALSE,
    include.constant, lambda=model$lambda, transform.pars=TRUE,
    fixed=NULL, init=NULL, method=c("CSS-ML","ML","CSS"), n.cond,
    optim.control=list(), kappa=1e6, model=NULL)
```

Arguments

`x`	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(x)). 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 x.
`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.
`transform.pars`	Logical. If true, the AR parameters are transformed to ensure that they remain in the region of stationarity. Not used for method="CSS".
`fixed`	optional numeric vector of the same length as the total number of parameters. If supplied, only NA entries in fixed will be varied. transform.pars=TRUE will be overridden (with a warning) if any AR parameters are fixed. It may be wise to set transform.pars=FALSE when fixing MA parameters, especially near non-invertibility.
`init`	optional numeric vector of initial parameter values. Missing values will be filled in, by zeroes except for regression coefficients. Values already specified in fixed will be ignored.
`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.
`n.cond`	Only used if fitting by conditional-sum-of-squares: the number of initial observations to ignore. It will be ignored if less than the maximum lag of an AR term.
`optim.control`	List of control parameters for optim.
`kappa`	the prior variance (as a multiple of the innovations variance) for the past observations in a differenced model. Do not reduce this.
`model`	Output from a previous call to `Arima`. If model is passed, this same model is fitted to `x` without re-estimating any parameters.

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

`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)))
```

---

arima.errors *ARIMA errors*

Description

Returns original time series after adjusting for regression variables. These are not the same as the residuals. If there are no regression variables in the ARIMA model, then the errors will be identical to the original series. If there are regression variables in the ARIMA model, then the errors will be equal to the original series minus the effect of the regression variables, but leaving in the serial correlation that is modelled with the AR and MA terms. If you want the "residuals", then use `residuals(z)`..

Usage

```
arima.errors(z)
```

Arguments

z	Fitted ARIMA model from `arima`

Value

A time series containing the "errors".

Author(s)

Rob J Hyndman

See Also

arima, residuals

Examples

```
www.fit <- auto.arima(WWWusage)
www.errors <- arima.errors(www.fit)
par(mfrow=c(2,1))
plot(WWWusage)
plot(www.errors)
```

---

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(x, 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), xreg=NULL,
     test=c("kpss","adf","pp"), seasonal.test=c("ocsb","ch"),
     allowdrift=TRUE, allowmean=TRUE, lambda=NULL, parallel=FALSE, num.cores=2)
```

Arguments

`x`	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.
xreg	Optionally, a vector or matrix of external regressors, which must have the same number of rows as x.
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.
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.

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))
```

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=TRUE,
  num.cores=2, bc.lower=0, bc.upper=1, ...)
```

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.
`...`	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, use.parallel=FALSE)
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")
```

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)
```

Arguments

x	a numeric vector or time series
lambda	transformation parameter

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

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))
```

---

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

Description

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

Usage

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

Arguments

x	a numeric vector or time series
h	Number of periods for forecasting.
alpha	Value of alpha. Default value is 0.1.

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 x 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

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

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

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, Yousaf Khan and Rob Hyndman

References

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

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, period2, h=2*max(period1,period2),
    alpha=NULL, beta=NULL, gamma=NULL, omega=NULL, phi=NULL,
    lambda=NULL, 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.
`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 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
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)

## End(Not run)

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)
```

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,
    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=TRUE`, `additive.only` is set to FALSE.
`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` (default), 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` *One-step in-sample forecasts using ARIMA models*

Description

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

Usage

```
## S3 method for class 'Arima'
fitted(object,...)
```

Arguments

`object`	An object of class "`Arima`". Usually the result of a call to `arima`.
`...`	Other arguments.

Value

A time series of the one-step forecasts.

Author(s)

Rob J Hyndman

See Also

`forecast.Arima`.

Examples

```
fit <- Arima(WWWusage,c(3,1,0))
plot(WWWusage)
lines(fitted(fit),col=2)
```

`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`.

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).

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, ...)
```

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.
`...`	Additional arguments affecting the forecasts produced. `forecast.ts` passes these to `forecast.ets` or `stlf` depending on the frequency of the time series.

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.

---

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$lambda,
    bootstrap=FALSE, npaths=5000, ...)
## S3 method for class 'ar'
forecast(object, h=10, level=c(80,95), fan=FALSE, lambda=NULL,
    bootstrap=FALSE, npaths=5000, ...)
## S3 method for class 'fracdiff'
forecast(object, h=10, level=c(80,95), fan=FALSE, lambda=object$lambda, ...)
```

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

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.
...	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, ...)
```

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.
...	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,...)
```

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.
`...`	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. That is x minus fitted values.
`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, 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.
`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.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(x, s.window=7, robust=FALSE, method=c("ets","arima"),
     modelfunction=NULL, etsmodel="ZZN", lambda=NULL, xreg=NULL,
     allow.multiplicative.trend=FALSE, ...)
stlf(x, h=frequency(x)*2, s.window=7, t.window=NULL, robust=FALSE, lambda=NULL, ...)
## S3 method for class 'stlm'
forecast(object, h = 2*object$m,
level = c(80, 95), fan = FALSE, lambda=object$lambda, 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, xreg=NULL, newxreg=NULL,
    allow.multiplicative.trend=FALSE, ...)
```

Arguments

x	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.
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.
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.
...	Other arguments passed to forecast.stl, modelfunction or forecastfunction.

Details

stlm takes a time series x, 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, ...)
```

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.
`...`	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))
```

`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)
```

`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

`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)
```

`logLik.ets` *Log-Likelihood of an ets object*

Description

Returns the log-likelihood of the ets model represented by `object` evaluated at the estimated parameters.

Usage

```
## S3 method for class 'ets'
logLik(object, ...)
```

Arguments

`object`	an object of class `ets`, representing an exponential smoothing state space model.
`...`	some methods for this generic require additional arguments. None are used in this method.

Value

the log-likelihood of the model represented by `object` evaluated at the estimated parameters.

Author(s)

Rob J Hyndman

References

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

`ets`

Examples

```
fit <- ets(USAccDeaths)
logLik(fit)
```

`ma` *Moving-average smoothing*

Description

Computes a simple moving average smoother.

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.

Value

Numerical time series object containing the smoothed values.

Author(s)

Rob J Hyndman

See Also

ksmooth, 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 x.

Usage

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

Arguments

x	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.

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)
```

---

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 periods 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")`.

Author(s)

Slava Razbash and Rob J Hyndman

Examples

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

Description

`naive()` returns forecasts and prediction intervals for an ARIMA(0,1,0) random walk model applied to x. `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(x, h=10, level=c(80,95), fan=FALSE, lambda=NULL)
snaive(x, h=2*frequency(x), level=c(80,95), fan=FALSE, lambda=NULL)
```

Arguments

`x`	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.

Details

These functions are simply convenient wrappers to `Arima` with the appropriate arguments to return naive and seasonal naive forecasts.

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, rwf

Examples

```
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.

Dickey DA and Fuller WA (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root", *Journal of the American Statistical Association* **74**:427-431.

Kwiatkowski D, Phillips PCB, Schmidt P and Shin Y (1992) "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root", *Journal of Econometrics* **54**:159-178.

Osborn DR, Chui APL, Smith J, and Birchenhall CR (1988) "Seasonality and the order of integration for consumption", *Oxford Bulletin of Economics and Statistics* **50**(4):361-377.

Osborn, D.R. (1990) "A survey of seasonality in UK macroeconomic variables", *International Journal of Forecasting*, **6**:327-336.

Said E and Dickey DA (1984), "Testing for Unit Roots in Autoregressive Moving Average Models of Unknown Order", *Biometrika* **71**:599-607.

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(x, p, P=1, size, repeats=20, lambda=NULL)
## S3 method for class 'nnetar'
forecast(object, h=ifelse(object$m > 1, 2 * object$m, 10),
    lambda=object$lambda, ...)
```

Arguments

x	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 plus 1.
repeats	Number of networks to fit with different random starting weights. These are then averaged when producing forecasts.
lambda	Box-Cox transformation parameter.
object	An object of class `nnetar` generated by `nnetar`.
h	Number of periods for forecasting.
...	Other arguments.

Details

A feed-forward neural network is fitted with lagged values of `x` 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(x)`. 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. The fitted model is called an NNAR(p,P) model and is analogous to an ARIMA(p,0,0)(P,0,0) model but with nonlinear functions.

Value

`nnetar` returns an object of class "`nnetar`". `forecast.nnetar` returns 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 `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
`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)
`...`	Other arguments

Author(s)

Rob J Hyndman

Examples

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

`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.

Usage

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

Arguments

`x`	Object of class “Arima” or “ar”.
`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

See Also

`Arima`, `ar`

Examples

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

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

plot(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.

Usage

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

Arguments

`x`	Object of class “ets”.
`...`	Other plotting parameters passed to `par`.

Value

None. Function produces a plot

Author(s)

Rob J Hyndman

See Also

`ets`

Examples

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

plot.forecast — *Forecast plot*

Description

Plots historical data with forecasts and prediction intervals.

Usage

```
## S3 method for class 'forecast'
plot(x, include, plot.conf=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 'splineforecast'
plot(x, fitcol=2, type="o", pch=19, ...)
```

Arguments

x	Forecast object produced by `forecast`.
include	number of values from time series to include in plot
plot.conf	Logical flag indicating whether to plot prediction intervals.
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 `shade=FALSE` and `plot.conf=TRUE`, the prediction intervals are plotted in this colour.
pi.lty	If `shade=FALSE` and `plot.conf=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.
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"`).
...	additional arguments to `plot`.

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

Examples

```
deaths.fit <- hw(USAccDeaths,h=48)
plot(deaths.fit)
```

---

rwf *Random Walk Forecast*

Description

Returns forecasts and prediction intervals for a random walk with drift model applied to x.

Usage

```
rwf(x, h=10, drift=FALSE, level=c(80,95), fan=FALSE, lambda=NULL)
```

Arguments

x	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.

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, the drift parameter c=0. Forecast standard errors allow for uncertainty in estimating the drift parameter.

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

See Also

Arima, meanf

Examples

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

---

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.

Value

Univariate time series.

Author(s)

Rob J Hyndman

See Also

stl, decompose, tbats.

Examples

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

---

seasonaldummy *Seasonal dummy variables*

Description

seasonaldummy and seasonaldummyf return matrices of dummy variables suitable for use in arima, lm or tslm. The last season is omitted and used as the control.

fourier and fourierf return matrices containing terms from a Fourier series, up to order K, suitable for use in arima, lm or tslm.

Usage

```
seasonaldummy(x)
seasonaldummyf(x,h)
fourier(x,K)
fourierf(x,K,h)
```

Arguments

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

Details

The number of dummy variables, or the period of the Fourier terms, is determined from the time series characteristics of `x`. The length of `x` also determines the number of rows for the matrices returned by `seasonaldummy` and `fourier`. The value of `h` determines the number of rows for the matrices returned by `seasonaldummyf` and `fourierf`. The values within `x` are not used in any function.

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

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(seasonaldummyf(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)

# Using Fourier series
X <- fourier(ldeaths,3)
deaths.lm  <- tslm(ldeaths ~ X)
ldeaths.fcast <- forecast(deaths.lm,
  data.frame(X=I(fourierf(ldeaths,3,36))))
plot(ldeaths.fcast)

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

`seasonplot` *Seasonal plot*

Description

Plots a seasonal plot as described in Hyndman and Athanasopoulos (2014, chapter 2).

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, ...)
```

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`)
`main`	Main title.
`xlab`	X-axis label.
`ylab`	Y-axis label.
`col`	Colour
`labelgap`	Distance between year labels and plotted lines
`...`	additional arguments to `plot`.

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

monthplot

Examples

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

---

ses *Exponential smoothing forecasts*

Description

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

Usage

```
ses(x, h=10, level=c(80,95), fan=FALSE,
    initial=c("optimal","simple"), alpha=NULL, ...)
holt(x, h=10, damped=FALSE, level=c(80,95), fan=FALSE,
    initial=c("optimal","simple"), exponential=FALSE,
    alpha=NULL, beta=NULL, ...)
hw(x, 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, ...)
```

Arguments

`x`	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.
`...`	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. That is x minus fitted values.
`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, ...)
```

Arguments

object	An object of class "ets", "Arima" or "ar".
nsim	Number of periods for the simulated series
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.
bootstrap	If TRUE, simulation uses resampled errors rather than normally distributed errors.
innov	A vector of innovations to use as the error series. If present, bootstrap and seed are ignored.
xreg	New values of xreg to be used for forecasting. Must have nsim rows.
lambda	Box-Cox parameter. If not NULL, the simulated series is transformed using an inverse Box-Cox transformation with parameter lamda.
...	Other arguments.

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`.

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

Arguments

`x`	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.
`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.

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

The main purpose of this function is to extract the values of a specific season 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, ...)
```

Arguments

`x`	a univariate time series to be subsetted
`subset`	optional logical expression indicating elements to keep; missing values are taken as false.
`month`	Character list of months to retain. Partial matching on month names used.
`quarter`	Numeric list of quarters to retain.
`season`	Numeric list of seasons to retain.
`...`	Other arguments, unused.

Value

If one season per year is extracted, then a ts object is returned with frequency 1. Otherwise, a numeric vector is returned with no ts attributes.

Author(s)

Rob J Hyndman

See Also

`subset`

Examples

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

`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 Reseach 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=TRUE,
    num.cores=2, bc.lower=0, bc.upper=1, ...)
```

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.

...
: 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, use.parallel=FALSE)
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(x, h=10, level=c(80,95), fan=FALSE)
```

Arguments

`x`	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.

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). Prediction intervals are computed using the underlying state space model.

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 loess for non-seasonal series and a periodic stl decompostion with seasonal series to identify and replace outliers. To estimate missing values, linear interpolation is used for non-seasonal series, and a periodic stl decompostion is used with seasonal 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

Examples

```
data(gold)
tsclean(gold)
```

---

tsdisplay *Time series display*

Description

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

Usage

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

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.
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.
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))
```

---

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, lambda=NULL, ...)
```

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.
lambda	Box-Cox transformation parameter. Ignored if NULL. Otherwise, data are transformed via a Box-Cox transformation.
...	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)

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 loess for non-seasonal series and a periodic stl decompostion with seasonal series to identify and replace outliers.

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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