Package ‘hts’

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hts-package  Hierarchical and grouped time series

Description

This package presents functions to create, plot and forecast hierarchical and grouped time series. In forecasting hierarchical and grouped time series, the base methods implemented include ETS, ARIMA and the naive (random walk) models. Forecasts for grouped time series are calibrated using bottom-up and optimal combination methods. Forecasts for hierarchical time series are distributed in the hierarchy using bottom-up, top-down, middle-out and optimal combination methods. Three top-down methods are available: the two Gross-Sohl methods and the forecast-proportion approach of Hyndman, Ahmed, and Athanasopoulos (2011).

Author(s)

Rob J Hyndman, Alan Lee, Earo Wang and Shanika L Wickramasuriya with contributions from Roman A Ahmed and Han Lin Shang to earlier versions of the package

References


In-sample or out-of-sample accuracy measures for forecast grouped and hierarchical model

Description

Returns a range of summary measures of the forecast accuracy. The function measures out-of-sample forecast accuracy based on (holdout data - forecasts) and in-sample accuracy at the bottom level when setting keep.fitted = TRUE in the forecast.gts. All measures are defined and discussed in Hyndman and Koehler (2006).

Usage

```r
## S3 method for class 'gts'
accuracy(f, test, levels, ...)
```

Arguments

- `f`: An object of class gts, containing the forecasted hierarchical or grouped time series. In-sample accuracy at the bottom level returns when `test` is missing.
- `test`: An object of class gts, containing the holdout hierarchical time series.
- `levels`: Return the specified level(s), when carrying out out-of-sample.
- `...`: Extra arguments to be ignored

Details

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

Value

Matrix giving forecast accuracy measures.

- `ME`: Mean Error
- `RMSE`: Root Mean Square Error
- `MAE`: Mean Absolute Error
- `MAPE`: Mean Absolute Percentage Error
- `MPE`: Mean Percentage Error
- `MASE`: Mean Absolute Scaled Error
Author(s)

Rob J Hyndman and Earo Wang

References


See Also

`hts`, `plot.gts`, `forecast.gts`, `accuracy`

Examples

```r
data <- window(htseg2, start = 1992, end = 2002)
test <- window(htseg2, start = 2003)
fcasts <- forecast(data, h = 5, method = "bu")
accuracy(fcasts, test)
accuracy(fcasts, test, levels = 1)
```

---

**aggts**

*Extract selected time series from a gts object*

Description

The time series from selected levels of a hierarchical/grouped time series or a forecasted hierarchical/grouped time series are returned as a multivariate time series.

Usage

```r
aggts(y, levels, forecasts = TRUE)
```

Arguments

- `y` An object of class `{gts}`.
- `levels` Integer(s) or string(s) giving the specified level(s).
- `forecasts` If `y` contains forecasts and historical data, then `forecasts` indicates whether to return the forecasts or the historical data. Otherwise it is ignored.

Author(s)

Earo Wang

See Also

`allts`
allts

Examples

    aggts(htseg1, levels = c(0, 2))
    aggts(infantgts, levels = "State")

allts

Extract all time series from a gts object

Description

The time series from all levels of a hierarchical/grouped time series or a forecasted hierarchi-
cal/grouped time series are returned as a multivariate time series.

Usage

    allts(y, forecasts = TRUE)

Arguments

y                     An object of class gts.
forecasts             If y contains forecasts and historical data, then forecasts indicates whether to
                      return the forecasts or the historical data. Otherwise it is ignored.

Author(s)

Rob J Hyndman

See Also

    aggts

Examples

    allts(htseg1)
**combinef**

*Optimally combine forecasts from a hierarchical or grouped time series*

**Description**

Using the method of Hyndman et al. (2011), this function optimally combines the forecasts at all levels of a hierarchical time series. The `forecast.gts` calls this function when the `comb` method is selected.

**Usage**

```r
combinef(fcasts, nodes, groups, weights = NULL, algorithms = c("lu", "cg", "chol", "recursive", "slm"), keep = c("gts", "all", "bottom"))
```

**Arguments**

- `fcasts` Matrix of forecasts for all levels of the hierarchical time series. Each row represents one forecast horizon and each column represents one time series from the hierarchy.
- `nodes` If the object class is `hts`, a list contains the number of child nodes referring to `hts`.
- `groups` If the object class is `gts`, a `gmatrix` is required, which is the same as `groups` in the function `gts`.
- `weights` A numeric vector. The default is `NULL` which means that ordinary least squares is implemented.
- `algorithms` An algorithm to be used for computing reconciled forecasts. See `forecast.gts` for details.
- `keep` Return a `gts` object or the the reconciled forecasts at the bottom level.

**Value**

Return the reconciled `gts` object or forecasts at the bottom level.

**Author(s)**

Alan Lee, Rob J Hyndman and Earo Wang

**References**

forecast.gts

See Also

hts, forecast.gts

Examples

```r
# hts example
## Not run: h <- 12
ally <- aggts(htseg1)
allf <- matrix(NA, nrow = h, ncol = ncol(ally))
for(i in 1:ncol(ally))
  allf[,i] <- forecast(auto.arima(ally[,i]), h = h)$mean
allf <- ts(allf, start = 51)
y.f <- combinef(allf, get_nodes(htseg1), weights = NULL, keep = "gts", algorithms = "lu")
plot(y.f)
## End(Not run)

# gts example
## Not run: abc <- ts(S + matrix(sort(rnorm(200)), ncol = 4, nrow = 50))
g <- rbind(c(1,1,2,2), c(1,2,1,2))
y <- gts(abc, groups = g)
h <- 12
ally <- aggts(y)
allf <- matrix(NA,nrow = h,ncol = ncol(ally))
for(i in 1:ncol(ally))
  allf[,i] <- forecast(auto.arima(ally[,i]),h = h)$mean
allf <- ts(allf, start = 51)
y.f <- combinef(allf, groups = get_groups(y), keep="gts", algorithms = "lu")
plot(y.f)
## End(Not run)
```

---

**forecast.gts**

*Forecast a hierarchical or grouped time series*

**Description**

Methods for forecasting hierarchical or grouped time series.

**Usage**

```r
## S3 method for class 'gts'
forecast(object, h = ifelse(frequency(object$hts) > 1L, 2L * frequency(object$hts), 10L), method = c("comb", "bu", "mo", "tdgsa", "tdgsf", "tdfp"), weights = c("wls", "ols", "mint", "nseries"), fmethod = c("ets", "arima", "rw"), algorithms = c("lu", "cg", "chol", "recursive", "slm"), covariance = c("shr", "sam"), keep.fitted = FALSE, keep.resid = FALSE, positive = FALSE, lambda = NULL, level, parallel = FALSE, num.cores = 2, FUN = NULL, xreg = NULL, newxreg = NULL, ...)
```
Arguments

- **object**: Hierarchical or grouped time series object of class \{gts\}
- **h**: Forecast horizon
- **method**: Method for distributing forecasts within the hierarchy. See details
- **weights**: Weights used for "optimal combination" method: weights="ols" uses an unweighted combination (as described in Hyndman et al 2011); weights="wls" uses weights based on forecast variances (as described in Hyndman et al 2015); weights="mint" uses a full covariance estimate to determine the weights (as described in Hyndman et al 2016); weights="nseries" uses weights based on the number of series aggregated at each node.
- **fmethod**: Forecasting method to use for each series.
- **algorithms**: An algorithm to be used for computing the combination forecasts (when method="comb"). The combination forecasts are based on an ill-conditioned regression model. "lu" indicates LU decomposition is used; "cg" indicates a conjugate gradient method; "chol" corresponds to a Cholesky decomposition; "recursive" indicates the recursive hierarchical algorithm of Hyndman et al (2015); "slm" uses sparse linear regression. Note that algorithms = "recursive" and algorithms = "slm" cannot be used if weights="mint".
- **covariance**: Type of the covariance matrix to be used with weights="mint": either a shrinkage estimator ("shr") with shrinkage towards the diagonal; or a sample covariance matrix ("sam").
- **keep.fitted**: If TRUE, keep fitted values at the bottom level.
- **keep.resid**: If TRUE, keep residuals at the bottom level.
- **positive**: If TRUE, forecasts are forced to be strictly positive (by setting lambda=0).
- **lambda**: Box-Cox transformation parameter.
- **level**: Level used for "middle-out" method (only used when method = "mo").
- **parallel**: If TRUE, import parallel package to allow parallel processing.
- **num.cores**: If parallel = TRUE, specify how many cores are going to be used.
- **FUN**: A user-defined function that returns an object which can be passed to the forecast function. It is applied to all series in order to generate base forecasts. When FUN is not NULL, fmethod, positive and lambda are all ignored. Suitable values for FUN are \texttt{tbats} and \texttt{stlf} for example.
- **xreg**: When fmethod = "arima", a vector or matrix of external regressors used for modelling, which must have the same number of rows as the original univariate time series
- **newxreg**: When fmethod = "arima", a vector or matrix of external regressors used for forecasting, which must have the same number of rows as the h forecast horizon
- **...**: Other arguments passed to \texttt{ets}, \texttt{auto.arima} or FUN.

Details

Base methods implemented include ETS, ARIMA and the naive (random walk) models. Forecasts are distributed in the hierarchy using bottom-up, top-down, middle-out and optimal combination methods.
Three top-down methods are available: the two Gross-Sohl methods and the forecast-proportion approach of Hyndman, Ahmed, and Athanasopoulos (2011). The "middle-out" method "mo" uses bottom-up ("bu") for levels higher than level and top-down forecast proportions ("tdfp") for levels lower than level.

For non-hierarchical grouped data, only bottom-up and combination methods are possible, as any method involving top-down disaggregation requires a hierarchical ordering of groups.

When xreg and newxreg are passed, the same covariates are applied to every series in the hierarchy.

Value

A forecasted hierarchical/grouped time series of class gts.

Author(s)

Earo Wang, Rob J Hyndman and Shanika L Wickramasuriya

References


See Also

hts, gts, plot.gts, accuracy.gts

Examples

```r
forecast(htseg1, h = 10, method = "bu", method = "arima")

## Not run:
forecast(
    htseg2, h = 10, method = "comb", algorithms = "lu",
    FUN = function(x) tbats(x, use.parallel = FALSE)
)

## End(Not run)
```
get_groups

Get nodes/groups from an hts/gts object

Description
Get nodes/groups from an hts/gts object

Usage
get_groups(y)

Arguments

y
An hts or gts object series.

gts
Create a grouped time series

Description
Method for creating grouped time series.

Usage
gts(y, groups, gnames = rownames(groups), characters)
is.gts(xts)

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

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

Arguments

y
A matrix or multivariate time series contains the bottom level series.

groups
Group matrix indicates the group structure, with one column for each series when completely disaggregated, and one row for each grouping of the time series. It allows either a numerical matrix or a matrix consisting of strings that can be used for labelling. If the argument characters is used, then groups will be automatically generated within the function.

gnames
Specify the group names.
A vector of integers, or a list containing vectors of integers, indicating the segments in which bottom level names can be read in order to construct the corresponding grouping matrix and its labels. A list class is used when a grouped time series includes one or more hierarchies. For example, a grouped time series may involve a geographical grouping and a product grouping, with each of them associated with a 2-level hierarchy. In this situation, a bottom level name such as "VICMelbAB" would indicate the state "VIC" (3 characters) followed by the city "Melb" (4 characters), then the product category "A" (1 character) followed by the sub-product category "B" (1 character). In this example, the specification of characters is list(c(3, 4), c(1, 1)), where the first element c(3, 4) corresponds to the geographical hierarchy and the second element corresponds to the product hierarchy. In the special case where there is a non-hierarchical grouped time series, a vector of integers is also possible. For example, a grouped time series may involve state, age and sex grouping variables. In this situation, a bottom level name such as "VIC1F" would indicate the state "VIC", age group "1" and sex "F". Because none of these is hierarchical, we could specify characters = list(3, 1, 1), or as a simple numeric vector: characters = c(3, 1, 1). This implies its non-hierarchical structure and its characters segments. Again, all bottom level names must be of the same length. Currently, the use of characters only supports 2-way cross-products for grouping variables. Specifying groups is more general (but more complicated), as any combination of grouping variables can be used.

xts gts object.

x gts object.

... Extra arguments passed to print and summary.

object gts object.

Value

bts Multivariate time series contains the bottom level series

groups Information about the groups of a grouped time series

labels Information about the labels that are used for plotting.

Author(s)

Earo Wang and Rob J Hyndman

References


See Also

hts, accuracy.gts, forecast.gts, plot.gts
Examples

# Example 1 illustrating the usage of the "groups" argument
abc <- ts(5 + matrix(sort(rnorm(1600)), ncol = 16, nrow = 160))
sex <- rep(c("female", "male"), each = 8)
state <- rep(c("NSW", "VIC", "QLD", "SA", "WA", "ACT", "TAS"), 2)
gc <- rbind(sex, state)  # a matrix consists of strings.
gn <- rbind(rep(1:2, each = 8), rep(1:8, 2))  # a numerical matrix
rownames(gc) <- rownames(gn) <- c("Sex", "State")
x <- gts(abc, groups = gc)
y <- gts(abc, groups = gn)

# Example 2 with two simple hierarchies (geography and product) to show the argument "characters"
bnames1 <- c("VICMelbAA", "VICMelbAB", "VICGeelAA", "VICGeelAB",
             "VICMelbBA", "VICMelbBB", "VICGeelBA", "VICGeelBB",
             "NSWSyndAA", "NSWSyndAB", "NSWWollAA", "NSWWollAB",
             "NSWSyndBA", "NSWSyndBB", "NSWWollBA", "NSWWollBB")
bts1 <- matrix(ts(rnorm(1600)), ncol = 16)
colnames(bts1) <- bnames1
x1 <- gts(bts1, characters = list(c(3, 4), c(1, 1)))

# Example 3 with a non-hierarchical grouped time series of 3 grouping variables (state, age and sex)
bnames2 <- c("VIC1F", "VIC1M", "VIC2F", "VIC2M", "VIC3F", "VIC3M",
             "NSW1F", "NSW1M", "NSW2F", "NSW2M", "NSW3F", "NSW3M")
bts2 <- matrix(ts(rnorm(1200)), ncol = 12)
colnames(bts2) <- bnames2
x2 <- gts(bts2, characters = c(3, 1, 1))

---

hts

Create a hierarchical time series

Description

Method for creating hierarchical time series.

Usage

hts(y, nodes, bnames = colnames(y), characters)

is.hts(xts)

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

## S3 method for class 'hts'
summary(object, ...)
Arguments

y
- A matrix or multivariate time series contain the bottom level series.

nodes
- A list contains the number of child nodes associated with each level, which indicates the hierarchical structure. The default is a simple hierarchy with only 2 levels (i.e. total and bottom). If the argument characters is used, nodes will be automatically generated within the function.

bnames
- The names of the bottom time series.

characters
- Integers indicate the segments in which the bottom level names can be read in order to construct the corresponding node structure and its labels. For instance, suppose one of the bottom series is named "VICMelb" referring to the city of Melbourne within the state of Victoria. Then characters would be specified as c(3, 4) referring to states of 3 characters (e.g., "VIC") and cities of 4 characters (e.g., "Melb") All the bottom names must be of the same length, with number of characters for each segment the same for all series.

xts
- hts object.

x
- hts object.

... Extra arguments passed to print and summary.

Value

bts
- Multivariate time series containing the bottom level series

nodes
- Information about the nodes of a hierarchical time series

labels
- Information about the labels that are used for plotting.

Author(s)

Earo Wang and Rob J Hyndman

References


See Also

gts, accuracy.gts, forecast.gts, plot.gts

Examples

# Example 1
# The hierarchical structure looks like 2 child nodes associated with level 1,
# which are followed by 3 and 2 sub-child nodes respectively at level 2.
nodes <- list(2, c(3, 2))
abc <- ts(5 + matrix(sort(rnorm(500)), ncol = 5, nrow = 100))
x <- hts(abc, nodes)

# Example 2
# Suppose we’ve got the bottom names that can be useful for constructing the node
# structure and the labels at higher levels. We need to specify how to split them
# in the argument “characters”.
library(hts)
abc <- ts(5 + matrix(sort(rnorm(1000)), ncol = 10, nrow = 10))
                    "B30A", "B30B", "B30C", "B40A", "B40B")
y <- hts(abc, characters = c(1, 2, 1))

htseg1  Simple examples of hierarchical time series.

Description

These are simulated data. htseg1 has three levels with a total of 8 series each of length 10. htseg2
has four levels with a total of 17 series each of length 16.

Format

Objects of class hts.

References

forecasts for hierarchical time series. Computational Statistics and Data Analysis, 55(9), 2579–

Examples

plot(htseg1)

infantgts Regional infant mortality counts across Australia from 1933 to 2003.

Description

These are infant mortality counts. This data set is an example of gts, where the total infant mortality
count in Australia can be first disaggregated by sex then by state, or vice versa.

Format

Objects of class gts.
MinT

References


Examples

```
plot(infantgts)
```

---

**MinT**  
*Trace minimization for hierarchical or grouped time series*

**Description**

Using the method of Wickramasuriya et al. (2015), this function combines the forecasts at all levels of a hierarchical or grouped time series. The `forecast.gts` calls this function when the MinT method is selected.

**Usage**

```
MinT(fcasts, nodes, groups, residual, covariance = c("shr", "sam"), algorithms = c("lu", "cg", "chol"), keep = c("gts", "all", "bottom"))
```

**Arguments**

- **fcasts**: Matrix of forecasts for all levels of a hierarchical or grouped time series. Each row represents one forecast horizon and each column represents one time series of aggregated or disaggregated forecasts.
- **nodes**: If the object class is hts, a list contains the number of child nodes referring to hts.
- **groups**: If the object is gts, a gmatrix is required, which is the same as groups in the function gts.
- **residual**: Matrix of insample residuals for all the aggregated and disaggregated time series. The columns must be in the same order as `fcasts`.
- **covariance**: Type of the covariance matrix to be used. Shrinking towards a diagonal unequal variances ("shr") or sample covariance matrix ("sam").
- **algorithms**: Algorithm used to compute inverse of the matrices.
- **keep**: Return a gts object or the reconciled forecasts at the bottom level.

**Value**

Return the reconciled gts object or forecasts at the bottom level.
Author(s)

Shanika L Wickramasuriya

References


See Also

hts, gts, forecast.gts, combinef

Examples

# hts example
## Not run: h <- 12
ally <- aggts(htseg1)
n <- nrow(ally)
p <- ncol(ally)
allf <- matrix(NA, nrow = h, ncol = p)
res <- matrix(NA, nrow = n, ncol = p)
for(i in 1:p)
{
  fit <- auto.arima(ally[, i])
  allf[, i] <- forecast(fit, h = h)$mean
  res[, i] <- na.omit(ally[, i] - fitted(fit))
}
allf <- ts(allf, start = 51)
y.f <- MinT(allf, get_nodes(htseg1), residual = res, covariance = "shr",
    keep = "gts", algorithms = "1u")
plot(y.f)
y.f_cg <- MinT(allf, get_nodes(htseg1), residual = res, covariance = "shr",
    keep = "all", algorithms = "cg")

## End(Not run)

# gts example
## Not run: abc <- ts(S + matrix(sort(rnorm(200)), ncol = 4, nrow = 50))
g <- rbind(c(1,1,2,2), c(1,2,1,2))
y <- gts(abc, groups = g)
h <- 12
ally <- aggts(y)
n <- nrow(ally)
p <- ncol(ally)
allf <- matrix(NA,nrow = h,ncol = ncol(ally))
res <- matrix(NA, nrow = n, ncol = p)
for(i in 1:p)
{
  fit <- auto.arima(ally[, i])
  allf[, i] <- forecast(fit, h = h)$mean
  res[, i] <- na.omit(ally[, i] - fitted(fit))
}
allf <- ts(allf, start = 51)
y.f <- MinT(allf, groups = get_groups(y), residual = res, covariance = "shr",
  keep = "gts", algorithms = "lu")
plot(y.f)
## End(Not run)

---

plot.gts

*Plot grouped or hierarchical time series*

**Description**

Method for plotting grouped or hierarchical time series and their forecasts.

**Usage**

```r
## S3 method for class 'gts'
plot(x, include, levels, labels = TRUE, col = NULL,
  color_lab = FALSE, ...)
```

**Arguments**

- `x`: An object of class `gts`.
- `include`: Number of values from historical time series to include in the plot of forecasted group/hierarchical time series.
- `levels`: Integer(s) or string(s) giving the specified levels(s) to be plotted.
- `labels`: If TRUE, plot the labels next to each series.
- `col`: Vector of colours, passed to `plot.ts` and to `lines`.
- `color_lab`: If TRUE, colour the direct labels to match line colours. If FALSE will be as per `par()$fg`.
- `...`: Other arguments passing to `plot.default`.

**Author(s)**

Rob J Hyndman and Earo Wang

**References**

smatrix

Summing matrix for hierarchical or grouped time series

Description
This function returns the summing matrix for a hierarchical or grouped time series, as defined in Hyndman et al. (2011).

Usage

smatrix(xts)

Arguments

xts Hierarchical or grouped time series of class gts.

Value
A numerical matrix.

Author(s)
Earo Wang

References

See Also

hts, gts.combinef

See Also

aggts

Examples

plot(htseg1, levels = c(0, 2))
plot(infantgts, include = 10, levels = "State")
plot(infantgts, include = 10, levels = "State",
    col = colours()[100:107], lty = 1:8, color_lab = TRUE)
**window.gts**  

**Examples**

```r
smatrix(htseg1)
```

---

**window.gts**  

*Time window of a gts object*

**Description**

Extracts a subset of the time series from a grouped time series object.

**Usage**

```r
## S3 method for class 'gts'
window(x, ...)
```

**Arguments**

- `x`  
  An object of class `gts`.
- `...`  
  All other arguments are passed to `window.ts`.

**Author(s)**

Rob J Hyndman

**Examples**

```r
window(htseg2, start = 2000, end = 2001)
```
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