Package 'ForwardSearch'

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Description Forward Search analysis of time series regressions. Implements the asymptotic theory developed in Johansen and Nielsen (2013, 2014).

License GPL-3

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`ForwardSearch-package` *Functions for Forward Search for regression models.*

Description

The Forward Search algorithm is an iterative algorithm for for multiple (time series) regression suggested by Hadi and Simonoff (1993) and developed further by Atkinson and Riani (2000). The algorithm starts with a robust estimate of the regression parameters and a sub-sample of size m_0 and iterates with a sequence of least squares steps. The asymptotic theory developed by Johansen and Nielsen (2013, 2014) is implemented.

Details

Package:	ForwardSearch
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Version:	1.0
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License:	GPL-3

The Forward Search algorithm is an iterative algorithm for for multiple (time series) regression suggested by Hadi and Simonoff (1993) and developed further by Atkinson and Riani (2000). The algorithm starts with a robust estimate of the regression parameters and a sub-sample of size m_0. A common choice for the initial estimator is the Least Trimmed Squares estimator of Rousseeuw (1984).

The algorithm is initiated by computing the absolute residuals for all n observations. The initial sub-sample consists of the observations with the smallest m_0 absolute residuals. We then run a regression on those m_0 observations and compute absolute residuals of all n observations. The observations with $m_0 + 1$ smallest residuals are then selected. The $m_0 + 1$ smallest residual is the forward residual. A new regression is performed on these $m_0 + 1$ observations. This is then iterated. Eventually the least squares estimator based on all n observations is computed.

The algorithm results in a sequence of forward residuals indexed by the sub-sample size m running from m_0 to $n - 1$. The idea is to monitor the plot of these and stop when the forward residuals become "large". Johansen and Nielsen (2013, 2014) have developed, respectively, pointwise and simultaneous confidence bands for estimators and forward residuals. These are implemented in the package.

The ForwardSearch package can be used as follows.

1. Execute the full Forward Search using `ForwardSearch.fit`.
2. Create the forward plot of the forward residuals using `ForwardSearch.plot`. This requires the output from above and a choice of reference distribution. The plot shows the scaled forward residuals from above along with simultaneous confidence bands. The user has to choose a "gauge", which is the expected fraction of falsely detected outliers that are tolerable when in fact there are no outliers. For instance a "gauge" of 0.01 indicates that in a sample of n=110

observations 1.1 outlier is found on average when there are none. The simultaneous confidence bands are calibrated so that the Forward Search stop when the fitted values exceed the chosen confidence bands the first time. This is a stopping time. The theory for this is given in Johansen and Nielsen.

3. Get the estimates of the stopped Forward Search using `ForwardSearch.stopped`. The user has to input the estimated stopping time. This also gives the rank of the selected and non-selected observations. These are the "good" and the "bad" observations.

Author(s)

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References

Atkinson, A.C. and Riani, M. (2000) *Robust Diagnostic Regression Analysis.* New York: Springer.

Hadi, A.S. and Simonoff, J.S. (1993) Procedures for the Identification of Multiple Outliers in Linear Models *Journal of the American Statistical Association* 88, 1264-1272.

Johansen, S. and Nielsen, B. (2013) Asymptotic analysis of the Forward Search. *Download*: Nuffield DP.

Johansen, S. and Nielsen, B. (2014) Outlier detection algorithms for least squares time series. *Download*: Nuffield DP.

Rousseeuw, P.J. (1984) Least median of squares regression. *Journal of the American Statistical Association* 79, 871-880.

See Also

Forward Search can alternatively be done by the package `forward`. `forward` version 1.0.3 includes functions for the analysis suggested in e.g. Atkinson and Riani (2000), but does not include the asymptotic theory of Johansen and Nielsen (2013, 2014). Matlab code for Forward Search is also available from www.riani.it.

Examples

```
#####################
# EXAMPLE 1
# using Fulton Fish data,
# see Johansen and Nielsen (2014).

# Call package
library(ForwardSearch)

# Call data
data(Fulton)
mdata <- as.matrix(Fulton)
n <- nrow(mdata)

# Identify variable to reproduce Johansen and Nielsen (2014)
q <- mdata[2:n ,9]
q_1 <- mdata[1:(n-1) ,9]
```

```
s <- mdata[2:n ,6]
x.q.s <- cbind(q_1,s)
colnames(x.q.s ) <- c("q_1","stormy")

# Fit Forward Search
FS95 <- ForwardSearch.fit(x.q.s,q,psi.0=0.95)
FS80 <- ForwardSearch.fit(x.q.s,q,psi.0=0.80)

# Forward plot of forward residuals scaled by variance estimate
# Note the variance estimate is not bias corrected
# This is taken into account in asymptotic theory
ForwardSearch.plot(FS95)
ForwardSearch.plot(FS80)

# Based on the plot of e.g. FS95 it is decided to stop at m=107
ForwardSearch.stopped(FS95,107)

# Alternatively use the file inst/extdata/Fulton.txt
# Data <- read.table(data/Fulton.txt,header=TRUE)
```

`ForwardSearch.fit` *Execute the Forward Search Algorithm.*

Description

Execute the Forward Search Algorithm. Based on Johansen & Nielsen (2013).

Usage

```
ForwardSearch.fit(x.1, y, psi.0 = 0.5, m.0 = NULL, beta.0 = NULL)
```

Arguments

`x.1`	Matrix of dimension n x (dim.x -1). Design matrix for regressors apart from constant.
`y`	Vector of dimension n. Dependent variable.
`psi.0`	proportion of observations in initial set of set of selected observations. Default is 0.5. Initial set has `round(n*psi.0)` observations.
`m.0`	Number of observations in initial set of selected observations. Default is NULL. If value is given this overrides `psi.0`.
`beta.0`	Vector of dimension dim.x. Initial estimator for regression coefficient. Default is NULL, which results in Least Trimmed Squares estimator through `beta.0 <- ltsReg(y~x.1,alpha=psi`

Details

Dimensions: n is the number of observations. dim.x is the number of regressors (including intercept).

Default is initial estimator is the Least Trimmed Squares estimator of Rousseeuw (1984) implemented as `ltsReg` in package `robustbase`.

The breakdown point of the initial Least Trimmed Squares estimator and the size of the initial subsample are both given by `psi.0`. Alternatively, a Least Trimmed Squares estimator with a particular breakdown point can be entered through the argument `beta.0`.

Value

`forward.beta`	Matrix of dimension n x p. Forward Search estimates of beta.
`forward.sigma2.biased`	Matrix of dimension n x 1. Forward Search estimates of sigma. Values are *not* bias corrected.
`forward.residual`	Matrix of dimension n x 1. Forward Search estimates of forward residuals. Values are *not* bias corrected.
`m.0`	Number of observations in initial set of selected observations.
`y`	Vector of dimension n. Dependent variable from argument.
`x`	Matrix of dimension n x dim.x. Design matrix for regressors. Dependent variable from argument augmented with constant. First column is constant.

Author(s)

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References

Johansen, S. and Nielsen, B. (2013) Asymptotic analysis of the Forward Search. *Download*: Nuffield DP.

Johansen, S. and Nielsen, B. (2014) Outlier detection algorithms for least squares time series. *Download*: Nuffield DP.

Rousseeuw, P.J. (1984) Least median of squares regression. *Journal of the American Statistical Association* 79, 871-880.

Examples

```
####################
# EXAMPLE 1
# using Fulton Fish data,
# see Johansen and Nielsen (2014).

# Call package
library(ForwardSearch)

# Call data
```

```
data(Fulton)
mdata <- as.matrix(Fulton)
n <- nrow(mdata)

# Identify variable to reproduce Johansen and Nielsen (2014)
q <- mdata[2:n ,9]
q_1 <- mdata[1:(n-1) ,9]
s <- mdata[2:n ,6]
x.q.s <- cbind(q_1,s)
colnames(x.q.s ) <- c("q_1","stormy")

# Fit Forward Search
FS95 <- ForwardSearch.fit(x.q.s,q,psi.0=0.95)
```

`ForwardSearch.plot` *Plots forward residuals with simultaneous confidence bands*

Description

Plots forward residuals with simultaneous confidence bands based on Johansen and Nielsen (2013, 2014).

Usage

```
ForwardSearch.plot(FS, ref.dist = "normal",
bias.correct = FALSE, return = FALSE, plot.legend = TRUE,
col = NULL, legend = NULL, lty = NULL, lwd = NULL,
main = NULL, type = NULL, xlab = NULL, ylab = NULL)
```

Arguments

`FS`	List. Value of the function `ForwardSearch.fit`.
`ref.dist`	Character. Reference distribution.
	"normal" standard normal distribution.
`bias.correct`	Logical. If FALSE do not bias correct variance, so plots have appearance similar to Atkinson and Riani (2000). If TRUE do bias correct variance, so plots start at origin. Default is FALSE.
`return`	Logical. Default is FALSE: do not return values.
`plot.legend`	Logical. Default is TRUE: include legend in plot.
`col`	`plot` parameter. Vector of 6 colours.
`legend`	`plot` parameter. Vector of 6 characters.
`lty`	`plot` parameter. Vector of 6 line types.
`lwd`	`plot` parameter. Vector of 6 line widths.
`main`	`plot` parameter. Character.

type	plot parameter. Charcater for plot type.
xlab	plot parameter. Charcater for x label.
ylab	plot parameter. Charcater for y label.

Value

ref.dist	Character. From argument.
bias.correct	Logical. From argument.
forward.residual.scaled	Vector. Forward residuals scaled by estimated variance. The estimated variance is or is not bias corrected depending on the choice of bias.correct.
forward.asymp.median	Vector. Asymptotic median.
forward.asymp.sdv	Vector. Asymptotic standard deviation. Not divided by squareroot of sample size.
cut.off	Matrix. Cut-offs taken from Table 3 of Johansen and Nielsen (2014).

Author(s)

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References

Johansen, S. and Nielsen, B. (2013) Asymptotic analysis of the Forward Search. *Download*: Nuffield DP.

Johansen, S. and Nielsen, B. (2014) Outlier detection algorithms for least squares time series. *Download*: Nuffield DP.

Examples

```
####################
# EXAMPLE 1
# using Fulton Fish data,
# see Johansen and Nielsen (2014).

# Call package
library(ForwardSearch)

# Call data
data(Fulton)
mdata <- as.matrix(Fulton)
n <- nrow(mdata)

# Identify variable to reproduce Johansen and Nielsen (2014)
q <- mdata[2:n ,9]
q_1 <- mdata[1:(n-1) ,9]
s <- mdata[2:n ,6]
x.q.s <- cbind(q_1,s)
```

```
colnames(x.q.s ) <- c("q_1","stormy")

# Fit Forward Search
FS95 <- ForwardSearch.fit(x.q.s,q,psi.0=0.95)

ForwardSearch.plot(FS95)
```

`ForwardSearch.pointwise.asymptotics`
Functions for asymptotic theory of Forward Search

Description

Computes functions appearing in asymptotic theory of Forward Search based on Johansen and Nielsen (2013).

Usage

```
ForwardSearch.pointwise.asymptotics(psi, ref.dist = "normal")
```

Arguments

`psi`	Number or vector. Takes value(s) in interval 0,1.
`ref.dist`	Character. Reference distribution
	"normal" Standard normal distribution

Details

The asymptotic theory is developed in Johansen and Nielsen (2013), see Section 2.2.

c and ψ are linked through $P(|\epsilon| < c) = \psi$, where ϵ is a random variable with the chosen reference distribution.

ζ is a consistency factor. Its square is defined as the truncated second moment $\tau = \int_{-c}^{c} x^2 f(x)dx$ divided by ψ.

ϖ is the asymptotic standard deviation resulting from Theorem 3.3.

Value

`varpi`	Number or vector. sdv for forward residuals normalized by variance estimator and multiplied by twice the reference densisty.
`zeta`	Number or vector. Consistency correction factor.
`sdv.unbiased`	Number or vector. varpi/2/f.
`sdv.biased`	Number or vector. varpi/2/f/zeta.
`c`	Number or vector. c (median in unbiased case).
`median.biased`	Number or vector. median (in biased case).

Author(s)

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References

Johansen, S. and Nielsen, B. (2013) Asymptotic analysis of the Forward Search. *Download*: Nuffield DP.

Examples

```
#####################
# EXAMPLE 1
# Suppose n=100. Get asymptotic values for grid psi = (1, ... ,n)/n

n <- 100
psi <- seq(1,n-1)/n
FS <- ForwardSearch.pointwise.asymptotics(psi)

# Plot for biased normalisation
# - matching choice of Atkinson and Riani (2000)

main <- "Pointwise confidence bands for n=100\n Biased normalisation"
ylab <-"forward residual asymptotics"
 plot(psi,FS$median.biased,ylim=c(0,3),ylab=ylab,main=main,type="l")
lines(psi,FS$median.biased-2*FS$sdv.biased/sqrt(n))
lines(psi,FS$median.biased+2*FS$sdv.biased/sqrt(n))

# Plot for unbiased normalisation

main <- "Pointwise confidence bands for n=100\n Unbiased normalisation"
ylab <-"forward residual asymptotics"
 plot(psi,FS$c,ylim=c(0,3),ylab=ylab,main=main,type="l")
lines(psi,FS$c-2*FS$sdv.unbiased/sqrt(n))
lines(psi,FS$c+2*FS$sdv.unbiased/sqrt(n))
```

ForwardSearch.stopped *Forward estimators after m steps*

Description

A Forward Search gives a sequence of regression estimators. This function gives the regression estimators when stopped at m.

Usage

```
ForwardSearch.stopped(FS, m)
```

Arguments

FS	List. Value of the function ForwardSearch.fit.
m	Integer. Stopping time.

Value

ranks.selected	Vector. Ranks of m observations in the selected set.
ranks.outliers	Vector. Ranks of n-m observations that are not selected. These are the "outliers". It is the complement to ranks.selected.
beta.m	Vector. Least squares estimator based on ranks.selected.
sigma2.biased	Scalar. Scalar. Least squares residual variance based on ranks.selected. Value is *not* bias corrected.

Author(s)

Bent Nielsen <bent.nielsen@nuffield.ox.ac.uk> 9 Sep 2014

References

Johansen, S. and Nielsen, B. (2013) Asymptotic analysis of the Forward Search. *Download*: Nuffield DP.

Johansen, S. and Nielsen, B. (2014) Outlier detection algorithms for least squares time series. *Download*: Nuffield DP.

Examples

```
#####################
# EXAMPLE 1
# using Fulton Fish data,
# see Johansen and Nielsen (2014).

# Call package
library(ForwardSearch)

# Call data
data(Fulton)
mdata <- as.matrix(Fulton)
n <- nrow(mdata)

# Identify variable to reproduce Johansen and Nielsen (2014)
q <- mdata[2:n ,9]
q_1 <- mdata[1:(n-1) ,9]
s <- mdata[2:n ,6]
x.q.s <- cbind(q_1,s)
colnames(x.q.s ) <- c("q_1","stormy")

# Fit Forward Search
FS95 <- ForwardSearch.fit(x.q.s,q,psi.0=0.95)
```

```
ForwardSearch.stopped(FS95,107)
```

`Fulton` *Fulton fish data*

Description

Data from Fulton fish market collected by Graddy (1995, 2006). See also Hendry and Nielsen (2007) and Johansen and Nielsen (2014)

Usage

```
data(Fulton)
```

Format

Matrix with 111 rows of daily data and 13 variables.

Details

Documentation on the Fulton Fish market and original data can be found in Graddy (1995, 2006). Documentation for aggregated data used here can be found in Angrist, Graddy and Imbens (2000). Data used as example in Hendry and Nielsen (2007). Downloaded from Econometric Modeling.

The data set comprises aggregated daily prices and quantities of whiting sold in the period 2 December 1991 to 8 May 1992. In particular it has the variables

Monday 1 if Monday, 0 otherwise.

Tuesday 1 if Tuesday, 0 otherwise.

Wednesday 1 if Wednesday, 0 otherwise.

Thursday 1 if Thursday, 0 otherwise

Date

Stormy 1 if Wave hight greater than 4.5 feet Wind speed greater than 18 knots Based on moving averages of the last three days' wind speed and wave height before the trading day, as measured off the coast of Long Island and reported in the New York Times boating forecast.

Mixed 1 if Wave hight greater than 3.8 feet Wind speed greater than 13 knots excluding stormy days. Based on moving averages of the last three days' wind speed and wave height before the trading day, as measured off the coast of Long Island and reported in the New York Times boating forecast.

LogPrice Prices are average prices in US dollars per pound.

LogQuantity Quantities are pounds of whiting per day.

Rainy 1 if rainy wheather on shore.

Cold 1 if cold wheather on shore.

Windspeed

Windspeed2 Square of windspeed.

Source

Angrist, J.D., Graddy, K. and Imbens, G.W. (2000) The interpretation of instrumental variables estimators in simultaneous equations models with an application to the demand for fish. *Review of Economic Studies* 67, 499-527.

Graddy, K. (1995) Testing for imperfect competition at the Fulton Fish Market. *RAND Journal of Economics* 26, 75-92.

Graddy, K. (2006) The Fulton Fish Market. *Journal of Economic Perspectives* 20, 207-220.

Hendry, D.F. and Nielsen, B. (2007) *Econometric Modeling*. Princeton University Press.

Johansen, S. and Nielsen, B. (2014) Outlier detection algorithms for least squares time series. *Download*: Nuffield DP.

Examples

```
data(Fulton)
```

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