Package: BinSegBstrap (via r-universe)

October 15, 2024

Title Piecewise Smooth Regression by Bootstrapped Binary Segmentation

Version 1.0-1

Depends R (>= 3.0.0)

Imports Rcpp (>= 0.12.3), stats

LinkingTo Rcpp

Suggests knitr

VignetteBuilder knitr

Description Provides methods for piecewise smooth regression. A piecewise smooth signal is estimated by applying a bootstrapped test recursively (binary segmentation approach). Each bootstrapped test decides whether the underlying signal is smooth on the currently considered subsegment or contains at least one further change-point.

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NeedsCompilation yes

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Date/Publication 2022-01-27 23:10:10 UTC

Repository https://florianpein.r-universe.dev

RemoteUrl https://github.com/cran/BinSegBstrap

RemoteRef HEAD

RemoteSha 5ab77b052aa370b49ac9e84652204103954ec979

Contents

BinSegBstrap-package *Piecewise smooth regression by bootstrapped binary segmentation*

Description

Provides methods for piecewise smooth regression. The main function `BinSegBstrap` estimates a piecewise smooth signal by applying a bootstrapped test recursively (binary segmentation approach). A single bootstrapped test for the hypothesis that the underlying signal is smooth versus the alternative that the underlying signal contains at least one change-point can be performed by the function `BstrapTest`. A single change-point is estimated by the function `estimateSingleCp`. More details can be found in the vignette. Parts of this work were inspired by Gijbels and Goderniaux (2004).

Acknowledgement

This work results from a summer research project at the University of Cambridge in 2019. Kate McDaid was supported by a bursary from the summer research programme of the Centre of Mathematics at the University of Cambridge. Florian Pein's position is funded by the EPSRC programme grant 'StatScale: Statistical Scalability for Streaming Data'.

References

Gijbels, I., Goderniaux, A-C. (2004) Bootstrap test for change-points in nonparametric regression. *Journal of Nonparametric Statistics* **16**(3-4), 591–611.

See Also

`BinSegBstrap`, `BstrapTest`, `estimateSingleCp`

Examples

```
n <- 200
signal <- sin(2 * pi * 1:n / n)
signal[51:100] <- signal[51:100] + 5
signal[151:200] <- signal[151:200] + 5

y <- rnorm(n) + signal

est <- BinSegBstrap(y = y)

plot(y)
lines(signal)
lines(est$est, col = "red")


n <- 100
signal <- sin(2 * pi * 1:n / n)
signal[51:100] <- signal[51:100] + 5
```

```
y <- rnorm(n) + signal

test <- BstrapTest(y = y)
est <- estimateSingleCp(y = y)

plot(y)
lines(signal)
lines(est$est, col = "red")
```

`BinSegBstrap` *Estimates a piecewise smooth signal*

Description

A piecewise smooth signal is estimated by applying `BstrapTest` recursively (binary segmentation approach). The final estimator is estimated by kernel smoothing on each segment separately; a joint bandwidth is selected by crossvalidation. More details can be found in the vignette.

Usage

```
BinSegBstrap(y, bandwidth, nbandwidth = 30L, B = 500L, alpha = 0.05,
             kernel = c("epanechnikov", "gaussian", "rectangular",
                        "triangular", "biweight", "silverman"))
```

Arguments

`y`	a numeric vector containing the data points
`bandwidth`	the bandwidth, i.e. a numeric with values between `1 / length(y)` and `0.5`. If missing `exp(seq(log(10 / length(y)), log(0.25), length.out = nbandwidth))` will be used. Crossvalidation will be performed if it is not a single numeric. Note that the test has almost no power when the bandwidth for the kernel smoother is too small, since then a change-point can be approximated well by a quickly changing smooth function.
`nbandwidth`	a single integer giving the number of bandwidths (see above) if `bandwidth` is missing
`B`	a single integer giving the number of bootstrap samples
`alpha`	a probability, i.e. a single numeric between 0 and 1, giving the significance level of the test
`kernel`	the kernel function, i.e. either a string or a function that takes a single numeric vector and returns the values of the kernel at those locations

Value

a `list` with the following components:
- est: the estimated signal
- cps: the estimated change-point locations
- bandwidth: the selected bandwidth

Examples

```
n <- 200
signal <- sin(2 * pi * 1:n / n)
signal[51:100] <- signal[51:100] + 5
signal[151:200] <- signal[151:200] + 5

y <- rnorm(n) + signal

# default bandwidth and kernel
est <- BinSegBstrap(y = y)

plot(y)
lines(signal)
lines(est$est, col = "red")

# fixed bandwidth
est <- BinSegBstrap(y = y, bandwidth = 0.1)

# user specified kernel
kernel <- function(x) 1 - abs(x) # triangular kernel
est <- BinSegBstrap(y = y, kernel = kernel)
```

`BstrapTest` *Bootstrap test for a single change-point*

Description

Tests whether the underlying signal is smooth or contains at least one change-point. The smooth alternative is estimated by a (crossvalidated) kernel smoother. The single change-point alternative is estimated by `estimateSingleCp`. Its estimated jump size is used as a test statistic and the critical value is obtained by bootstrapping. More details can be found in the vignette.

Usage

```
BstrapTest(y, bandwidth, nbandwidth = 30L, B = 500L, alpha = 0.05,
           kernel = c("epanechnikov", "gaussian", "rectangular",
                      "triangular", "biweight", "silverman"))
```

Arguments

`y`	a numeric vector containing the data points
`bandwidth`	the bandwidth, i.e. a numeric with values between `1 / length(y)` and `0.5`. If missing `exp(seq(log(10 / length(y)), log(0.25), length.out = nbandwidth))` will be used. Crossvalidation will be performed if it is not a single numeric. Note that the test has almost no power when the bandwidth for the kernel smoother is too small, since then a change-point can be approximated well by a quickly changing smooth function.

nbandwidth	a single integer giving the number of bandwidths (see above) if bandwidth is missing
B	a single integer giving the number of bootstrap samples
alpha	a probability, i.e. a single numeric between 0 and 1, giving the significance level of the test
kernel	the kernel function, i.e. either a string or a function that takes a single numeric vector and returns the values of the kernel at those locations

Value

a list with the following components:
- piecewiseSignal: the estimated signal with a single change-point
- cp: the estimated change-point location
- size: the estimated jump size
- bandwidth: the selected bandwidth for the piecewise signal
- bandwidthSmooth: the selected bandwidth for the smooth signal
- smoothSignal: the estimated smooth signal
- critVal: the by bootstrapping obtained critical value
- pValue: the p-Value of the test
- outcome: a boolean saying whether the test rejects the hypothesis of a smooth signal

Examples

```
n <- 100
signal <- sin(2 * pi * 1:n / n)
signal[51:100] <- signal[51:100] + 5

y <- rnorm(n) + signal

# default bandwidth and kernel
test <- BstrapTest(y = y)

if (test$outcome) {
  # null hypothesis of a smooth signal is rejected
  estimatedSignal <- test$piecewiseSignal
} else {
  # null hypothesis of a smooth signal is accepted
  estimatedSignal <- test$smoothSignal
}

plot(y)
lines(signal)
lines(estimatedSignal, col = "red")

# fixed bandwidth
test <- BstrapTest(y = y, bandwidth = 0.1)

# user specified kernel
kernel <- function(x) 1 - abs(x) # triangular kernel
test <- BstrapTest(y = y, kernel = kernel)
```

`estimateSingleCp` *Estimation of a single change-point*

Description

Estimates a single change-point in an otherwise smooth function. The change-point location is estimated as the maximum of the differences of left and right sided running means. The estimate left and right of the change-point are obtained by kernel smoothers. Windows of the running mean and kernel bandwidth are chosen by crossvalidation. More details can be found in the vignette.

Usage

```
estimateSingleCp(y, bandwidth, nbandwidth = 30L,
                 kernel = c("epanechnikov", "gaussian", "rectangular",
                            "triangular", "biweight", "silverman"))
```

Arguments

`y`	a numeric vector containing the data points
`bandwidth`	the bandwidth, i.e. a numeric with values between `1 / length(y)` and `0.5`. If missing `exp(seq(log(2 / length(y)), log(0.25), length.out = nbandwidth))` will be used. Crossvalidation will be performed if it is not a single numeric
`nbandwidth`	a single integer giving the number of bandwidths (see above) if `bandwidth` is missing
`kernel`	the kernel function, i.e. either a string or a function that takes a single numeric vector and returns the values of the kernel at those locations

Value

a `list` with the following components:
- est: the estimated function with a single change-point
- cp: the estimated change-point location
- size: the estimated jump size
- bandwidth: the selected bandwidth

Examples

```
n <- 100
signal <- sin(2 * pi * 1:n / n)
signal[51:100] <- signal[51:100] + 5

y <- rnorm(n) + signal

# default bandwidth and kernel
est <- estimateSingleCp(y = y)

plot(y)
```

```
lines(signal)
lines(est$est, col = "red")

# fixed bandwidth
est <- estimateSingleCp(y = y, bandwidth = 0.1)

# user specified kernel
kernel <- function(x) 1 - abs(x) # triangular kernel
est <- estimateSingleCp(y = y, kernel = kernel)
```

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