

# Package: MonotonicityTest (via r-universe)

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**Type** Package

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**Title** Nonparametric Bootstrap Test for Regression Monotonicity

**Version** 1.0

**Description** Implements nonparametric bootstrap tests for detecting monotonicity in regression functions from Hall, P. and Heckman, N. (2000) <[doi:10.1214/aos/1016120363](https://doi.org/10.1214/aos/1016120363)> Includes tools for visualizing results using Nadaraya-Watson kernel regression and supports efficient computation with 'C++'.

**License** GPL

**Encoding** UTF-8

**RoxygenNote** 7.3.2

**LinkingTo** Rcpp, RcppEigen

**Imports** Rcpp (>= 1.0.13-1), parallel, stats, graphics, ggplot2 (>= 3.0.0), rlang

**Suggests** testthat (>= 3.0.0)

**Config/testthat/edition** 3

**NeedsCompilation** yes

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## Contents

create_kernel_plot . . . . .	2
monotonicity_test . . . . .	3

<b>Index</b>	<b>6</b>
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create\_kernel\_plot      *Generate Kernel Plot*

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### Description

Creates a scatter plot of the input vectors  $X$  and  $Y$ , and overlays a Nadaraya-Watson kernel regression curve using the specified bandwidth.

### Usage

```
create_kernel_plot(X, Y, bandwidth = bw.nrd(X) * (length(X)^-0.1))
```

### Arguments

<code>X</code>	Vector of x values.
<code>Y</code>	Vector of y values.
<code>bandwidth</code>	Kernel bandwidth used for the Nadaraya-Watson estimator. Default is calculated as $\text{bw.nrd}(X) * (\text{length}(X) ^ -0.1)$ .

### Value

A ggplot object containing the scatter plot with the kernel regression curve.

### References

Nadaraya, E. A. (1964). On estimating regression. *Theory of Probability and Its Applications*, **9**(1), 141–142.

Watson, G. S. (1964). Smooth estimates of regression functions. *Sankhyā: The Indian Journal of Statistics, Series A*, 359-372.

### Examples

```
# Example 1: Basic plot on quadratic function
seed <- 42
set.seed(seed)
X <- runif(500)
Y <- X ^ 2 + rnorm(500, sd = 0.1)
plot <- create_kernel_plot(X, Y, bandwidth = bw.nrd(X) * (length(X) ^ -0.1))
```

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monotonicity\_test      *Perform Monotonicity Test*

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### Description

Performs a monotonicity test between the vectors  $X$  and  $Y$  as described in Hall and Heckman (2000). This function uses a bootstrap approach to test for monotonicity in a nonparametric regression setting.

### Usage

```
monotonicity_test(  
  X,  
  Y,  
  bandwidth = bw.nrd(X) * (length(X)^-0.1),  
  boot_num = 200,  
  m = floor(0.05 * length(X)),  
  ncores = 1,  
  negative = FALSE,  
  seed = NULL  
)
```

### Arguments

X	Numeric vector of predictor variable values. Must not contain missing or infinite values.
Y	Numeric vector of response variable values. Must not contain missing or infinite values.
bandwidth	Numeric value for the kernel bandwidth used in the Nadaraya-Watson estimator. Default is calculated as $\text{bw.nrd}(X) * (\text{length}(X) ^ -0.1)$ .
boot_num	Integer specifying the number of bootstrap samples. Default is 200.
m	Integer parameter used in the calculation of the test statistic. Corresponds to the minimum window size to calculate the test statistic over or a "smoothing" parameter. Lower values increase the sensitivity of the test to local deviations from monotonicity. Default is $\text{floor}(0.05 * \text{length}(X))$ .
ncores	Integer specifying the number of cores to use for parallel processing. Default is 1.
negative	Logical value indicating whether to test for a monotonic decreasing (negative) relationship. Default is FALSE.
seed	Optional integer for setting the random seed. If NULL (default), the global random state is used.

**Details**

The test evaluates the following hypotheses:

$H_0$ : The regression function is monotonic

- *Non-decreasing* if `negative = FALSE`
- *Non-increasing* if `negative = TRUE`

$H_A$ : The regression function is not monotonic

**Value**

A list with the following components:

- `p` The p-value of the test. A small p-value (e.g.,  $< 0.05$ ) suggests evidence against the null hypothesis of monotonicity.
- `dist` The distribution of test statistic under the null from bootstrap samples. The length of `dist` is equal to `boot_num`.
- `stat` The test statistic  $T_m$  calculated from the original data.
- `plot` A ggplot object with a scatter plot where the points of the "critical interval" are highlighted. This critical interval is the interval where  $T_m$  is greatest.
- `interval` Numeric vector containing the indices of the "critical interval". The first index indicates where the interval starts, and the second indicates where it ends in the sorted X vector.

**Note**

For large datasets (e.g.,  $n \geq 6500$ ) this function may require significant computation time due to having to compute the statistic for every possible interval. Consider reducing `boot_num`, using a subset of the data, or using parallel processing with `ncores` to improve performance.

In addition to this, a minimum of 300 observations is recommended for kernel estimates to be reliable.

**References**

Hall, P., & Heckman, N. E. (2000). Testing for monotonicity of a regression mean by calibrating for linear functions. *The Annals of Statistics*, **28**(1), 20–39.

**Examples**

```
# Example 1: Usage on monotonic increasing function
# Generate sample data
seed <- 42
set.seed(seed)

X <- runif(500)
Y <- 4 * X + rnorm(500, sd = 1)
result <- monotonicity_test(X, Y, boot_num = 25, seed = seed)

print(result$p)
print(result$stat)
```

```
print(result$dist)
print(result$interval)

# Example 2: Usage on non-monotonic function
seed <- 42
set.seed(seed)

X <- runif(500)
Y <- (X - 0.5) ^ 2 + rnorm(500, sd = 0.5)
result <- monotonicity_test(X, Y, boot_num = 25, seed = seed)

print(result$p)
print(result$stat)
print(result$dist)
print(result$interval)
```

# Index

`create_kernel_plot`, [2](#)

`monotonicity_test`, [3](#)