Package 'pc'

March 30, 2026

Title Pattern Causality Analysis

Version 0.1

Description Infer causation from observational data through pattern causality analysis (PC), with original algorithm for time series data from Stavroglou et al. (2020) <doi:10.1073/pnas.1918269117>, as well as methodological extensions for spatial cross-sectional data introduced by Zhang & Wang (2025) <doi:10.1080/13658816.2025.2581207>, together with a systematic description proposed in Runge et al. (2023) <doi:10.1038/s43017-023-00431-y>.

License GPL-3

Encoding UTF-8

RoxygenNote 7.3.3

URL https://stscl.github.io/pc/, https://github.com/stscl/pc

BugReports https://github.com/stscl/pc/issues

Depends R (>= 4.1.0)

LinkingTo Rcpp, RcppThread

Imports methods, sdsfun, sf, terra

Suggests Rcpp, RcppThread, readr, infoxtr, spEDM, tEDM

NeedsCompilation yes

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Repository CRAN

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ops   *Optimal Parameter Search for Pattern Causality*

Description

Optimal Parameter Search for Pattern Causality

Usage

```
## S4 method for signature 'data.frame'
ops(
  data,
  target,
  source,
  E = 3:5,
  k = E + 1,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  maximize = c("positive", "negative", "dark"),
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(E),
  higher.parallel = TRUE,
  h = 0
)

## S4 method for signature 'sf'
ops(
  data,
  target,
  source,
  E = 3:5,
  k = E + 2,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  maximize = c("positive", "negative", "dark"),
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(E),
```

```
    higher.parallel = TRUE,
    nb = NULL
)

## S4 method for signature 'SpatRaster'
ops(
  data,
  target,
  source,
  E = 3:5,
  k = E + 2,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  maximize = c("positive", "negative", "dark"),
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(E),
  higher.parallel = TRUE
)
```

Arguments

`data`	Observation data.
`target`	Integer of column indice for the target variable.
`source`	Integer of column indice for the source variable.
`E`	(optional) Embedding dimensions.
`k`	(optional) Number of nearest neighbors used for projection.
`tau`	(optional) Step of lag.
`style`	(optional) Embedding style (`0` includes current state, `1` excludes it).
`lib`	(optional) Libraries indices.
`pred`	(optional) Predictions indices.
`maximize`	(optional) Causality metric to maximize: one of "positive", "negative", or "dark".
`dist.metric`	(optional) Distance measure to be used.
`zero.tolerance`	(optional) Maximum number of zeros tolerated in signature space.
`relative`	(optional) Whether to calculate relative changes in embedding.
`weighted`	(optional) Whether to weight causal strength.
`threads`	(optional) Number of threads used.
`higher.parallel`	(optional) Whether to use a higher level of parallelism.
`h`	(optional) Prediction horizon.
`nb`	(optional) Neighbours list.

Value

A list.

param The selected optimal parameter combination.

xmap A data.frame containing cross-mapping performance across parameter settings.

Examples

```
columbus = sf::read_sf(system.file("case/columbus.gpkg", package="spEDM"))
pc::ops(columbus, 1, 3, E = 5:10, maximize = "negative", threads = 1)
```

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pc   *Pattern Causality*

Description

Pattern Causality

Usage

```
## S4 method for signature 'data.frame'
pc(
  data,
  target,
  source,
  libsizes = NULL,
  E = 3,
  k = E + 1,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  boot = 99,
  random = TRUE,
  seed = 42L,
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(libsizes),
  higher.parallel = TRUE,
  verbose = TRUE,
  h = 0
)

## S4 method for signature 'sf'
```

```
pc(
  data,
  target,
  source,
  libsizes = NULL,
  E = 3,
  k = E + 2,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  boot = 99,
  random = TRUE,
  seed = 42L,
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(libsizes),
  higher.parallel = TRUE,
  verbose = TRUE,
  nb = NULL
)

## S4 method for signature 'SpatRaster'
pc(
  data,
  target,
  source,
  libsizes = NULL,
  E = 3,
  k = E + 2,
  tau = 1,
  style = 1,
  lib = NULL,
  pred = NULL,
  boot = 99,
  random = TRUE,
  seed = 42L,
  dist.metric = c("euclidean", "manhattan", "maximum"),
  zero.tolerance = max(k),
  relative = TRUE,
  weighted = TRUE,
  threads = length(libsizes),
  higher.parallel = TRUE,
  verbose = TRUE
)
```

Arguments

`data`	Observation data.
`target`	Integer of column indice for the target variable.
`source`	Integer of column indice for the source variable.
`libsizes`	(optional) Number of observations used.
`E`	(optional) Embedding dimensions.
`k`	(optional) Number of nearest neighbors used for projection.
`tau`	(optional) Step of lag.
`style`	(optional) Embedding style (`0` includes current state, `1` excludes it).
`lib`	(optional) Libraries indices.
`pred`	(optional) Predictions indices.
`boot`	(optional) Number of bootstraps to perform.
`random`	(optional) Whether to use random sampling.
`seed`	(optional) Random seed.
`dist.metric`	(optional) Distance measure to be used.
`zero.tolerance`	(optional) Maximum number of zeros tolerated in signature space.
`relative`	(optional) Whether to calculate relative changes in embedding.
`weighted`	(optional) Whether to weight causal strength.
`threads`	(optional) Number of threads used.
`higher.parallel`	
	(optional) Whether to use a higher level of parallelism.
`verbose`	(optional) Whether to show the progress bar.
`h`	(optional) Prediction horizon.
`nb`	(optional) Neighbours list.

Value

A list (when `libsizes` is NULL) or data.frame. If `libsizes` is NULL, a list with two components is returned:

causality A data.frame containing per-sample causality results.

summary A data.frame summarizing overall causality metrics.

Note

`pc` only supports numeric input data.

References

Stavroglou, S.K., Pantelous, A.A., Stanley, H.E., Zuev, K.M., 2020. Unveiling causal interactions in complex systems. Proceedings of the National Academy of Sciences 117, 7599–7605.

Examples

```
columbus = sf::read_sf(system.file("case/columbus.gpkg", package="spEDM"))
pc::pc(columbus, 1, 3, E = 5, k = 10, threads = 1)
```

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