Package ‘sindyr’

May 1, 2024

Type Package

Title Sparse Identification of Nonlinear Dynamics

Version 0.2.4

Date 2024-04-30

Author Rick Dale and Harish S. Bhat

Maintainer Rick Dale <racdale@gmail.com>

Description This implements the Brunton et al (2016; PNAS <doi:10.1073/pnas.1517384113>) sparse identification algorithm for finding ordinary differential equations for a measured system from raw data (SINDy). The package includes a set of additional tools for working with raw data, with an emphasis on cognitive science applications (Dale and Bhat, 2018 <doi:10.1016/j.cogsys.2018.06.020>). See <https://github.com/racdale/sindyr> for examples and updates.

Depends R (>= 3.4), arrangements, matrixStats, igraph, graphics, grDevices

Imports pracma

License GPL (>= 2)

Collate 'windowed_sindy.R' 'sindy.R' 'features.R' 'finite_differences.R' 'finite_difference.R' 'lorenzattractor.R'

NeedsCompilation no

Repository CRAN

Date/Publication 2024-05-01 06:00:02 UTC

R topics documented:

---

sindyr-package *Sparse Identification of Nonlinear Dynamics*

Description

This implements the Brunton et al (2016; PNAS, doi: 10.1073/pnas.1517384113) sparse identification algorithm for finding ordinary differential equations for a measured system from raw data (SINDy). The package includes a set of additional tools for working with raw data, with an emphasis on cognitive science applications (Dale and Bhat, 2018, doi: 10.1016/j.cogsys.2018.06.020). See <https://github.com/racdale/sindyr> for examples and updates.

Details

Package:	sindyr
Type:	Package
Version:	0.2.1
Date:	2018-09-10
License:	GPL >= 2

`sindy`: Main function to infer coefficient matrix for set of ODEs.

`windowed_sindy`: Sliding window function to obtain SINDy results across segments of a time series.

`features`: Function for generation feature space from measured variables.

`finite_differences`: Numerical differentiation over multiple columns.

`finite_difference`: Numerical differential of a vector.

Author(s)

Rick Dale and Harish S. Bhat

References

Dale, R. and Bhat, H. S. (2018). Equations of mind: data science for inferring nonlinear dynamics of socio-cognitive systems. Cognitive Systems Research, 52, 275-290.

Brunton, S. L., Proctor, J. L., and Kutz, J. N. (2016). Discovering governing equations from data by sparse identification of nonlinear dynamical systems. Proceedings of the National Academy of Sciences, 113(15), 3932-3937.

For further examples and links to other materials see: https://github.com/racdale/sindyr

Examples

```
# example to reconstruct of
```

```
# the Lorenz system

library(sindyr)

set.seed(666)
dt = .001
numsteps = 10000; dt = dt; sigma = 10; r = 28; b = 2.6;
xs = data.frame(lorenzattractor(numsteps, dt, sigma, r, b))
colnames(xs) = list('x','y','z')
xs = xs[2000:nrow(xs),] # cut out initialization

Theta = features(xs,3) # grid of features
par(mfrow=c(7,3),oma = c(2,0,0,0) + 0.1,mar = c(1,1,1,1) + 0.1)
for (i in 2:ncol(Theta)) {
 plot(Theta[,i],xlab='t',main=gsub(':','',colnames(Theta)[i]),type='l',xaxt='n',yaxt='n')
}

sindy.obj = sindy(xs=xs,dt=dt,lambda=.5) # let's reconstruct
sindy.obj$B # Lorenz equations
```

`features` *Build a matrix of features for SINDy*

Description

Takes a raw matrix of data and converts into polynomial features

Arguments

`x`	Raw data to be converted into features
`polyorder`	Order of polynomials (including k-th self products)
`intercept`	Include column of 1s in features to represent intercept (default = TRUE)

Details

Expands raw data into a set of polynomial features.

Value

Returns a new matrix of data with features from raw data

Author(s)

Rick Dale and Harish S. Bhat

finite_difference — *Estimate derivative of variable with finite differences*

Description

Estimates first-order derivatives of a vector

Arguments

`x`	Raw data to be differentiated
`S`	Sample rate of data to return derivatives using raw time

Details

Uses simplest version of finite-difference method (window size 2) to numerically estimate derivative of a time series.

Value

Returns first-order numerical derivatives estimated from data.

Author(s)

Rick Dale and Harish S. Bhat

finite_differences — *Estimate derivatives of multiple variables with finite differences*

Description

Estimates first-order derivatives of column vectors of a matrix

Arguments

`xs`	Raw data to be differentiated (matrix)
`S`	Sample rate of data to return derivatives using raw time

Details

Uses simplest version of finite-difference method (window size 2) to numerically estimate derivative of multiple columnar time series.

Value

Returns first-order numerical derivatives estimated from data.

Author(s)

Rick Dale and Harish S. Bhat

`lorenzattractor` *Simulate the Lorenz Attractor*

Description

An implementation of the Lorenz dynamical system, which describes the motion of a possible particle, which will neither converge to a steady state, nor diverge to infinity; but rather stay in a bounded but 'chaotically' defined region, i.e., an attractor.

Usage

```
lorenzattractor(numsteps, dt, sigma, r, b)
```

Arguments

`numsteps`	The number of simulated points
`dt`	System parameter
`sigma`	System parameter
`r`	System parameter
`b`	System parameter

Value

It returns a matrix with the 3 dimensions of the Lorenz

Author(s)

Moreno I. Coco (moreno.cocoi@gmail.com)

References

Lorenz, Edward Norton (1963). Deterministic nonperiodic flow. Journal of the Atmospheric Sciences 20(2) 130-141.

Examples

```
## initialize the parameters
numsteps = 2 ^ 11; dt = .01; sigma = 10; r = 28; b = 8/3;

res = lorenzattractor(numsteps, dt, sigma, r, b)
```

`sindy` *Run main SINDy function*

Description

Estimates coefficients for set of ordinary differential equations governing system variables.

Arguments

`xs`	Matrix of raw data
`dx`	Matrix of main system variable dervatives; if NULL, it estimates with finite differences from xs
`dt`	Sample interval, if data continuously sampled; default = 1
`Theta`	Matrix of features; if not supplied, assumes polynomial features of order 3
`lambda`	Threshold to use for iterated least squares sparsification (Brunton et al.)
`B.expected`	The function will compute a goodness of fit if supplied with an expected coefficient matrix B; default = NULL
`verbose`	Verbose mode outputs Theta and dx values in their entirety; default = FALSE
`fit.its`	Number of iterations to conduct the least-square threshold sparsification; default = 10
`plot.eq.graph`	When set to TRUE, prints an igraph plot of variables as a graph structure; default = FALSE

Details

Uses the "left-division" approach of Brunton et al. (2016), and implements least-squares sparsification, and outputs coefficients after iterations stabilize.

Value

Returns a matrix B of coefficients specifying the relationship between dx and Theta

Author(s)

Rick Dale and Harish S. Bhat

References

Dale, R. and Bhat, H. S. (in press). Equations of mind: data science for inferring nonlinear dynamics of socio-cognitive systems. Cognitive Systems Research.

Brunton, S. L., Proctor, J. L., and Kutz, J. N. (2016). Discovering governing equations from data by sparse identification of nonlinear dynamical systems. Proceedings of the National Academy of Sciences, 113(15), 3932-3937.

`windowed_sindy` *Run SINDy over time windows*

Description

Run SINDy on raw data with a sliding window approach

Arguments

`xs`	Matrix of raw data
`dx`	Matrix of main system variable dervatives; if NULL, it estimates with finite differences from xs
`dt`	Sample interval, if data continuously sampled; default = 1
`Theta`	Matrix of features; if not supplied, assumes polynomial features of order 3
`lambda`	Threshold to use for iterated least squares sparsification (Brunton et al.)
`fit.its`	Number of iterations to conduct the least-square threshold sparsification; default = 10
`B.expected`	The function will compute a goodness of fit if supplied with an expected coefficient matrix B; default = NULL
`window.size`	Size of window to segment raw data as separate time series; defaults to deciles
`window.shift`	Step sizes across windows, permitting overlap; defaults to deciles

Details

A convenience function for extracting a list of coefficients on segments of a time series. This facilitates using SINDy output as source of descriptive measures of dynamics.

Value

It returns a list of coefficients Bs containing B coefficients at each window

Author(s)

Rick Dale and Harish S. Bhat

References

Dale, R. and Bhat, H. S. (in press). Equations of mind: data science for inferring nonlinear dynamics of socio-cognitive systems. Cognitive Systems Research.

Index