Package 'bayesWatch'

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Type Package

Title Bayesian Change-Point Detection for Process Monitoring with Fault Detection

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Description Bayes Watch fits an array of Gaussian Graphical Mixture Models to groupings of homogeneous data in time, called regimes, which are modeled as the observed states of a Markov process with unknown transition probabilities. In doing so, Bayes Watch defines a posterior distribution on a vector of regime assignments, which gives meaningful expressions on the probability of every possible change-point. Bayes Watch also allows for an effective and efficient fault detection system that assesses what features in the data where the most responsible for a given change-point. For further details, see: Alexander C. Murph et al. (2023) <doi:10.48550/arXiv.2310.02940>.

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Imports Rcpp (>= 1.0.7), parallel (>= 3.6.2), Matrix, Hotelling, CholWishart, ggplot2, gridExtra (>= 0.9.1), BDgraph, methods, MASS, stats, ess

LinkingTo Rcpp, RcppArmadillo, RcppEigen, Matrix, CholWishart, BH

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Contents

`bayeswatch` *Fit a bayesWatch object.*

Description

Main method of package. MCMC sampling for change-point probabilities with fault detection according to the model by Murph et al. 2023. Creates a bayesWatch object for analysis of change-points.

Usage

```
bayeswatch(
  data_woTimeValues,
  time_of_observations,
  time_points,
  variable_names = 1:ncol(data_woTimeValues),
  not.cont = NULL,
  iterations = 100,
  burnin = floor(iterations/2),
  lower_bounds = NULL,
  upper_bounds = NULL,
  ordinal_indicators = NULL,
  list_of_ordinal_levels = NULL,
  categorical_indicators = NULL,
  previous_states = NULL,
  previous_model_fits = NULL,
  linger_parameter = 500,
  move_parameter = 100,
  g.prior = 0.2,
  set_G = NULL,
  wishart_df_initial = 1500,
  lambda = 1500,
  g_sampling_distribution = NULL,
```

```
  n.cores = 1,
  scaleMatrix = NULL,
  allow_for_mixture_models = FALSE,
  dirichlet_prior = 0.001,
  component_truncation = 7,
  regime_truncation = 15,
  hyperprior_b = 20,
  model_params_save_every = 5,
  simulation_iter = NULL,
  T2_window_size = 3,
  determining_p_cutoff = FALSE,
  prob_cutoff = 0.5,
  model_log_type = "NoModelSpecified",
  regime_selection_multiplicative_prior = 2,
  split_selection_multiplicative_prior = 2,
  is_initial_fit = TRUE,
  verbose = FALSE
)
```

Arguments

data_woTimeValues	matrix. Raw data matrix without datetime stamps.
time_of_observations	vector. Datetime stamps for every data instance in data_woTimeValues.
time_points	vector. Time points that mark each 'day' of time. Range should include every datetime in time_of_observations.
variable_names	vector. Vector of names of columnsof data_woTimeValues.
not.cont	vector. Indicator variable as to which columns are discrete.
iterations	integer. Number of MCMC samples to take (including burn-in).
burnin	integer. Number of burn-in samples. iterations > burnin necessarily.
lower_bounds	vector. Lower bounds for each data column.
upper_bounds	vector. Upper bounds for each data column.
ordinal_indicators	vector. Discrete values, one for each column, indicating which variables are ordinal.
list_of_ordinal_levels	vector. Discrete values, one for each column, indicating which variables are part of the same ordinal group.
categorical_indicators	vector. Each nominal d categorical variable must be broken down into d different indicator variables. This vector marks which variables are such indicators.
previous_states	vector. Starting regime vector, if known, of the same length as the number of 'days' in time_points.

previous_model_fits
: rlist. Starting parameter fits corresponding to regime vector previous_states.

linger_parameter
: float. Prior parameter for Markov chain probability matrix. Larger = less likely to change states.

move_parameter
: float. Prior parameter for Markov chain probability matrix. Larger = more likely to change states.

g.prior
: float in (0,1). Prior probability on edge inclusion for graph structure G.

set_G
: matrix. Starting graph structure, if known.

wishart_df_initial
: integer (>= 3). Starting DF for G-Wishart prior.

lambda
: float. Parameter for NI-G-W prior, controls affect of precision sample on the center sample.

g_sampling_distribution
: matrix. Prior probability on edge inclusion if not uniform across G.

n.cores
: integer. Number of cores available for parallelization.

scaleMatrix
: matrix. Parameter for NI-G-W prior.

allow_for_mixture_models
: logical. Whether or not method should fix mixture distributions to regimes.

dirichlet_prior
: float. Parameter for the dirichlet process for fitting components in the mixture model.

component_truncation
: integer. Maximum component allowed. Should be sufficiently large.

regime_truncation
: integer. Maximum regime allowed. Should be sufficiently large.

hyperprior_b
: integer. Hyperprior on Wishart distribution fit to the scaleMatrix.

model_params_save_every
: integer. How frequently to save model fits for the fault detection method.

simulation_iter
: integer. Used for simulation studies. Deprecated value at package launch.

T2_window_size
: integer. Length of sliding window for Hotelling T2 pre-step. Used when an initial value for previous_states is not provided.

determining_p_cutoff
: logical. Method for estimating the probability cutoff on the posterior distribution for determining change-points. Deprecated at package launch date.

prob_cutoff
: float. Changepoints are determined (for fault detection process) if posterior probability exceeds this value.

model_log_type
: character vector. The type of log (used to distinguish logfiles).

regime_selection_multiplicative_prior
: float. Must be >=1. Gives additional probability to the most recent day for the selection of a new split point.

split_selection_multiplicative_prior
: float.

is_initial_fit logical. True when there is no previously fit bayesWatch object fed through the algorithm..

verbose logical. Prints verbose model output for debugging when TRUE. It is highly recommended that you pipe this to a text file.

Value

bayesWatch object. A model fit for the analysis of posterior change-points and fault detection.

Examples

```
library(bayesWatch)
data("full_data")
data("day_of_observations")
data("day_dts")

x       = bayeswatch(full_data, day_of_observations, day_dts,
                     iterations = 500, g.prior = 1, linger_parameter = 20, n.cores=3,
                     wishart_df_initial = 3, hyperprior_b = 3, lambda = 5)

print(x)
plot(x)
detect_faults(x)
```

---

detect_faults *Determine the cause of a change-point.*

Description

Prints out fault detection graphics given a bayesWatch object. This method can only be run if fault detection was run on the bayesWatch fit (if model_params_save_every < iterations).

Usage

```
detect_faults(regime_fit_object)
```

Arguments

regime_fit_object
bayesWatch object. Fit with main method of package.

Value

ggplot object. Fault detection graphs.

full_data *Simulated Data with Imposed Change-points.*

Description

Data simulated using the BDgraph package. A change-point is imposed between days 5 and 6. The change only occurs in variables 3 and 4.

Usage

```
full_data

day_of_observations

day_dts
```

Format

'full_data' is a matrix, the latter two are vectors.

Details

'full_data' is a data frame with 1,000 rows and 5 columns. 'day_of_observations'; is a timestamp of each of 'full_data''s 1,000 rows. 'day_dts'; is a vector of unique elements from 'day_of_observations'..

Examples

```
full_data
day_of_observations
day_dts
```

get_point_estimate *Create an estimate on posterior distribution of change-points.*

Description

Given a bayesWatch object and a probability cutoff, finds change-points.

Usage

```
get_point_estimate(regime_fit_object, prob_cutoff)
```

Arguments

regime_fit_object	bayesWatch object. Fit with the bayesWatch method.
prob_cutoff	float in (0,1). Posterior probabilities above this cutoff will be considered change-points.

Value

vector. Indicator values corresponding to change-point locations.

`plot.bayesWatch` *Print function for a bayesWatch object. Prints only the posterior change-point probabilities.*

Description

Print function for a bayesWatch object. Prints only the posterior change-point probabilities.

Arguments

`x`	bayesWatch object. Fit from bayesWatch main method.
`...`	Additional plotting arguments.

`print.bayesWatch` *Print function for a bayesWatch object. Prints only the posterior change-point probabilities.*

Description

Print function for a bayesWatch object. Prints only the posterior change-point probabilities.

Arguments

`x`	bayesWatch object. Fit from bayesWatch main method.
`...`	Additional plotting arguments.

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