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 homo-
geneous data in time, called regimes, which are modeled as the observed states of a Markov pro-
cess with unknown transition probabilities. In doing so, Bayes Watch defines a posterior distri-
bution on a vector of regime assignments, which gives meaningful expressions on the probabil-
ity of every possible change-point. Bayes Watch also allows for an effective and effi-
cient fault detection system that assesses what features in the data where the most responsi-
ble for a given change-point. For further details, see: Alexan-
der C. Murph et al. (2023) <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

Depends R (>= 3.5.0)

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R topics documented:

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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.

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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.

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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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