

Package ‘bayesWatch’

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Type Package

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

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Maintainer Alexander C. Murph <murph290@gmail.com>

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](https://doi.org/10.48550/arXiv.2310.02940)>.

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Author Alexander C. Murph [aut, cre],
Reza Mohammadi [ctb, cph],
Alex Lenkoski [ctb, cph],
Andrew Johnson [ctb]

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bayeswatch	<i>Fit a bayesWatch object.</i>
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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 columns of `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.

<code>move_parameter</code>	float. Prior parameter for Markov chain probability matrix. Larger = more likely to change states.
<code>g.prior</code>	float in (0,1). Prior probability on edge inclusion for graph structure G.
<code>set_G</code>	matrix. Starting graph structure, if known.
<code>wishart_df_initial</code>	integer (≥ 3). Starting DF for G-Wishart prior.
<code>lambda</code>	float. Parameter for NI-G-W prior, controls affect of precision sample on the center sample.
<code>g_sampling_distribution</code>	matrix. Prior probability on edge inclusion if not uniform across G.
<code>n.cores</code>	integer. Number of cores available for parallelization.
<code>scaleMatrix</code>	matrix. Parameter for NI-G-W prior.
<code>allow_for_mixture_models</code>	logical. Whether or not method should fix mixture distributions to regimes.
<code>dirichlet_prior</code>	float. Parameter for the dirichlet process for fitting components in the mixture model.
<code>component_truncation</code>	integer. Maximum component allowed. Should be sufficiently large.
<code>regime_truncation</code>	integer. Maximum regime allowed. Should be sufficiently large.
<code>hyperprior_b</code>	integer. Hyperprior on Wishart distribution fit to the scaleMatrix.
<code>model_params_save_every</code>	integer. How frequently to save model fits for the fault detection method.
<code>simulation_iter</code>	integer. Used for simulation studies. Deprecated value at package launch.
<code>T2_window_size</code>	integer. Length of sliding window for Hotelling T2 pre-step. Used when an initial value for previous_states is not provided.
<code>determining_p_cutoff</code>	logical. Method for estimating the probability cutoff on the posterior distribution for determining change-points. Deprecated at package launch date.
<code>prob_cutoff</code>	float. Changepoints are determined (for fault detection process) if posterior probability exceeds this value.
<code>model_log_type</code>	character vector. The type of log (used to distinguish logfiles).
<code>regime_selection_multiplicative_prior</code>	float. Must be ≥ 1 . Gives additional probability to the most recent day for the selection of a new split point.
<code>split_selection_multiplicative_prior</code>	float.
<code>is_initial_fit</code>	logical. True when there is no previously fit bayesWatch object fed through the algorithm..
<code>verbose</code>	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

```
data("full_data", package = "bayesWatch")
head(full_data)
data("day_of_observations", package = "bayesWatch")
head(day_of_observations)
data("day_dts", package = "bayesWatch")
head(day_dts)

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	<i>Determine the cause of a change-point.</i>
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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	<i>Simulated Data with Imposed Change-points.</i>
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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.

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

```
data("full_data", package = "bayesWatch")
head(full_data)
data("day_of_observations", package = "bayesWatch")
head(day_of_observations)
data("day_dts", package = "bayesWatch")
head(day_dts)
```

get_point_estimate	<i>Create an estimate on posterior distribution of change-points.</i>
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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	<i>Print function for a bayesWatch object. Prints only the posterior change-point probabilities.</i>
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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	<i>Print function for a bayesWatch object. Prints only the posterior change-point probabilities.</i>
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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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