# Package 'rtmpt'

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**Version** 0.1-14

**Title** Fitting RT-MPT Models

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**Depends** R (>= 3.0.0)

**Imports** coda, data.table, loo, methods, stats, stringr, utils

**Suggests** knitr

**VignetteBuilder** knitr

**NeedsCompilation** yes

**SystemRequirements** GNU Scientific Library version >= 2.5

**Description** With this package it is possible to fit response-
time extended multinomial processing tree (RT-MPT)
models by Klauer and Kellen (2018) <doi:10.1016/j.jmp.2017.12.003>. This model class not only incorporate
frequencies like traditional multinomial processing tree (MPT) models, but also latencies. This enables it
to estimate process completion times and encoding plus motor execution times next to the process probabilities
of traditional MPTs. rtmpt is a Bayesian framework and posterior samples are sampled using a Metropolis-Gibbs
sampler like the one described in the Klauer and Kellen (2018), but with some modifications. Other than in
the original C++ program we use the free and open source GNU Scientific Library (GSL). There is also the
possibility to suppress single process completion times.

**License** GPL (>= 2)

**Encoding** UTF-8

**LazyData** true

**RoxygenNote** 6.1.1

**Archs** i386, x64

# R topics documented:



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`fit_rtmpt` *Posterior sample, diagnostics and some optional stuff*

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## Description

Given model and data, this function calls ana altered version of the C++ program by Klauer and Kellen (2018) to sample from the posterior distribution via a Metropolis-Gibbs sampler and storing it in an mcmc.list called `samples`. Posterior predictive checks developed by Klauer (2010), deviance information criterion (DIC; Spiegelhalter et al., 2002), 99% and 95% highest density intervals (HDI) together with the median will be provided for the main parameters in a list called `diags`. Optionally, the `indices` widely applicable information criterion (WAIC; Watanabe, 2010; Vehtari et al., 2017) and leave-one-out cross-validation (LOO; Vehtari et al., 2017) can be saved. Additionally the log-likelihood (`LogLik`) can also be stored. Some specifications of the function call are also saved in `specs`.

## Usage

```
fit_rtmpt(model, data, Nchains = 4, Nsamples = 5000, Nwarmup = 200,
  thin = 1, Rhat_max = 1.05, Irep = 1000, prior_params = NULL,
  indices = FALSE, save_log_lik = FALSE)
```

## Arguments

| | |
|---|---|
| `model` | A list of the class `rtmpt_model`. |
| `data` | Optimally, a list of class `rtmpt_data`. Also possible is a `data.frame` or a path to the text file. Both, `data.frame` and the text file must contain the column names "subj", "group", "tree", "cat", and "rt" preferably but not necessarily in this order. The values of the latter must be in milliseconds. It is always advised to use `to_rtmpt_data` first, which gives back an `rtmpt_data` list with informations about the changes in the data, that were needed. |
| `Nchains` | Number of chains to use. Default is 4. Must be larger than 1 and smaller or equal to 16. |
| `Nsamples` | Number of samples per chain. Default is 5000. |
| `Nwarmup` | Number of warm-up samples. Default is 200. |
| `thin` | Thinning factor. Default is 1. |
| `Rhat_max` | Maximal Potential scale reduction factor: A threshold that needs to be reached before the actual sampling starts. Default is 1.05 |
| `Irep` | Every `Irep` samples an interim state with the current maximal potential scale reduction factor is shown. Default is 1000. The following statements must hold true for `Irep`: |

- Nwarmup is smaller than or equal to Irep,
- Irep is a multiple of thin and
- Nsamples is a multiple of Irep / thin.

prior_params Named list with prior parameters. All parameters have default values, that lead to uninformative priors. Allowed parameters are:

- mean_of_exp_mu_beta: This is the a priori expected exponential rate (E(exp(beta)) = E(lambd and 1/mean_of_exp_mu_beta is the a priori expected process time (1/E(exp(beta)) = E(tau)) The default mean is set to 10, such that the expected a priori process time is 0.1 seconds.
- var_of_exp_mu_beta: The a priori group-specific variance of the exponential rates. Since exp(mu_beta) is Gamma distributed, the rate of the distribution is just mean divided by variance and the shape is the mean times the rate. The default is set to 100.
- mean_of_mu_gamma: This is the a priori expected *mean parameter* of the encoding and response execution times, which follow a normal distribution truncated from below at zero, so E(mu_gamma) < E(gamma). The default is 0.
- var_of_mu_gamma: The a priori group-specific variance of the *mean parameter*. Its default is 10.
- mean_of_omega_sqr: This is the a priori expected residual variance (E(omega^2)). Its distribution differs from the one used in the paper. Here it is a Gamma distribution instead of an improper one. The default is 0.005.
- var_of_omega_sqr: The a priori variance of the residual variance (Var(omega^2)). The default is 0.01. The default of the mean and variance is equivalent to a shape and rate of 0.0025 and 0.5, respectivly.
- df_of_sigma_sqr: A priori degrees of freedom for the individual variance of the response executions. The individual variance has a scaled inverse chi-squared prior with df_of_sigma_sqr degrees of freedom and omega^2 as scale. 2 is the default and it should be an integer.
- sf_of_scale_matrix_SIGMA: The original scaling matrix (S) of the (scaled) inverse Wishart distribution for the process related parameters is an identity matrix S=I. sf_of_scale_matrix_SIGMA is a scaling factor, that scales this matrix (S=sf_of_scale_matrix_SIGMA*I). Its default is 1.
- sf_of_scale_matrix_GAMMA: The original scaling matrix (S) of the (scaled) inverse Wishart distribution for the encoding and motor execution parameters is an identity matrix S=I. sf_of_scale_matrix_GAMMA is a scaling factor, that scales this matrix (S=sf_of_scale_matrix_GAMMA*I). Its default is 1.
- prec_epsilon: This is epsilon in the paper. It is the precision of mu_alpha and all xi (scaling parameter in the scaled inverse Wishart distribution). Its default is also 1.
- add_df_to_invWish: If P is the number of parameters or rather the size of the scale matrix used in the (scaled) inverse Wishart distribution then add_df_to_invWish is the number of degrees of freedom that can be added to it. So DF = P + add_df_to_invWish. The default for add_df_to_invWish is 1, such that the correlations are uniformly distributed within [-1, 1].

indices Model selection indices. If set to TRUE the log-likelihood for each iteration and trial will be stored temporarily and with that the WAIC and LOO will be calculated via the loo package. If you want to have this log-likelihood matrix stored in the output of this function, you can set save_log_lik to TRUE. The default for indices is FALSE.

`save_log_lik` If set to `TRUE` and `indices = TRUE` the log-likelihood matrix for each iteration and trial will be saved in the output as a matrix. Its default is `FALSE`.

## Value

A list of the class `rtmpt_fit` containing

- `samples`: the posterior samples as an `mcmc.list` object,
- `diags`: some diagnostics like deviance information criterion, posterior predictive checks for the frequencies and latencies, potential scale reduction factors, and also the 99% and 95% HDIs and medians for the group-level parameters,
- `specs`: some model specifications like the model, arguments of the model call, and information about the data transformation,
- `indices` (optional): if enabled, WAIC and LOO,
- `LogLik` (optional): if enabled, the log-likelihood matrix used for WAIC and LOO.

## Author(s)

Raphael Hartmann

## References

Klauer, K. C. (2010). Hierarchical multinomial processing tree models: A latent-trait approach. *Psychometrika, 75(1)*, 70-98.

Klauer, K. C., & Kellen, D. (2018). RT-MPTs: Process models for response-time distributions based on multinomial processing trees with applications to recognition memory. *Journal of Mathematical Psychology, 82*, 111-130.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., & Van Der Linde, A. (2002). Bayesian measures of model complexity and fit. *Journal of the royal statistical society: Series b (statistical methodology), 64(4)*, 583-639.

Vehtari, A., Gelman, A., & Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing, 27(5)*, 1413-1432.

Watanabe, S. (2010). Asymptotic equivalence of Bayes cross validation and widely applicable information criterion in singular learning theory. *Journal of Machine Learning Research, 11(Dec)*, 3571-3594.

## Examples

```
################################################################################
# Detect-Guess variant of the Two-High Threshold model.
# The encoding and motor execution times are assumed to be equal for each response.
################################################################################

mdl_2HTM <- "
# targets
do+(1-do)*g
(1-do)*(1-g)

# lures
(1-dn)*g
dn+(1-dn)*(1-g)
```

```
# do: detect old; dn: detect new; g: guess
"

model <- to_rtmpt_model(mdl_file = mdl_2HTM)

## Not run:
# this is not a working example since rtmpt_data.txt does not exist.
# Type ?SimData for a working example.
data <- read.table(file = "./rtmpt_data.txt", header = TRUE)

data_list <- to_rtmpt_data(raw_data = data, model = model)

rtmpt_out <- fit_rtmpt(model = model, data = data_list)

## End(Not run)
```

---

`set_params` *Set constants for probability parameters and suppress process times in a* `rtmpt_model` *list*

---

## Description

By using `parameter = "probs"` you can specify which of the probability parameters should be set to a constant by using values between zero and one. If you use `NA` the probability will be estimated. By using `parameter = "tau_minus"` or `parameter = "tau_plus"` you can suppress process times/rates. Here `0` will suppress the named process and `NA` allows the process time/rate to be estimated.

## Usage

```
set_params(model, parameter, names, values = NA)
```

## Arguments

| | |
|---|---|
| `model` | A list of the class `rtmpt_model`. |
| `parameter` | Character of length one indicating the parameter to change. Allowed characters:<br>• "probs": probability parameters<br>• "tau_minus": rate parameters of the exponential distribution of the process times that lead to a negative outcome<br>• "tau_plus": rate parameters of the exponential distribution of the process times that lead to a positive outcome |
| `names` | Character vector with process names. |
| `values` | Numerical vector of length `length(names)`. By using `parameter = "probs"` you have the following options<br>• `NA`: estimate the named probability<br>• `0 < values < 1`: set the named probability to a constant value between zero and one<br>Example: `set_params(model = model, parameter = "probs", names = c("do", "dn", "g"), v` will set the guessing "old" (g) to the constant `0.5` in the 2HT model. By using `parameter = "tau_minus"` or `parameter = "tau_plus"` you have two options: |

- `NA`: estimate the process time/rate
- `0`: suppress the process time/rate

Example: `set_params(model = model, parameter = "tau_minus", names = c("do", "dn", "g"` will suppress the process-completion time for guessing "new" in the 2HT model. This of course does not make sense here, but for some models it might be useful if you assume that a time-consuming process is not associated with certain process-outcome pairs (e.g., for technical parameters not corresponding to a psychological process).

## Value

A list of the class `rtmpt_model`.

## Author(s)

Raphael Hartmann

## See Also

`set_resps`

## Examples

```
################################################################################
# Detect-Guess variant of the Two-High Threshold model.
# The encoding and motor execution times are assumed to be equal for each category.
# The process completion times for both failed detections will be suppressed.
################################################################################

mdl_2HTM <- "
# targets
do+(1-do)*g
(1-do)*(1-g)

# lures
(1-dn)*g
dn+(1-dn)*(1-g)

# do: detect old; dn: detect new; g: guess
"


model <- to_rtmpt_model(mdl_file = mdl_2HTM)

## removing the process times for the failed detection ("tau_minus")
## of the detection parameters ("dn", "do")
model <- set_params(model = model, parameter = "tau_minus",
                    names = c("dn", "do"), values = c(0,0))
```

set_resps *Set responses in a* rtmpt_model

## Description

Change the responses for a tree and the categories within that tree.

## Usage

```
set_resps(model, tree, categories, values = 0)
```

## Arguments

| | |
|---|---|
| model | A list of the class rtmpt_model. |
| tree | Character or numerical value of the tree for which the responses should be changed. |
| categories | Character or numerical vector identifying category/ies within the specified tree for which the responses should be changed. |
| values | Numerical vector of length length(categories) providing the responses. Default is 0. |

## Value

A list of the class rtmpt_model.

## Author(s)

Raphael Hartmann

## See Also

set_params

## Examples

```
########################################################################
# Detect-Guess variant of the Two-High Threshold model.
# The encoding and motor execution times will be set to different values
#   for each response.
########################################################################

mdl_2HTM <- "
# targets
do+(1-do)*g
(1-do)*(1-g)

# lures
(1-dn)*g
dn+(1-dn)*(1-g)

# do: detect old; dn: detect new; g: guess
"
```

```
model <- to_rtmpt_model(mdl_file = mdl_2HTM)

## changing the model to have two different encoding and response execution
## times for "old" and "new" responses.
for(i in c(0,1)) model <- set_resps(model = model, tree = i,
                                    categories = i*2+1, values = 1)
```

---

SimData *Data simulated from the restricted 2HTM*

---

## Description

Data set generated from a restricted Two-High Threshold model.

## Usage

```
SimData
```

## Format

A data frame with five variables:

`subj` subjects number

`group` group label of the subjects

`tree` condition of the current trial

`cat` observed response category

`rt` observed response time in ms

## Details

Fourty subjects with thirty trials per condition (Studied items, new Items) were simulated.

## Examples

```
######################################################################
# Detect-Guess variant of the restricted Two-High Threshold model.
######################################################################

head(SimData)

mdl_2HTM <- "
# targets
d+(1-d)*g
(1-d)*(1-g)

# lures
(1-d)*g
d+(1-d)*(1-g)

# d: detect; g: guess
"
```

```
model <- to_rtmpt_model(mdl_file = mdl_2HTM)

data <- to_rtmpt_data(raw_data = SimData, model = model)

## Not run:
# this might take some time to run
rtmpt_out <- fit_rtmpt(model = model, data = data)

# convergence
## traceplot and summary of the first six parameters
plot(rtmpt_out$samples[,1:6])
summary(rtmpt_out$samples[,1:6])

## End(Not run)
```

---

`to_rtmpt_data` *Transform data for use in* `fit_rtmpt`

---

## Description

Transform data, such that it can be used in `fit_rtmpt`. This implies changing each value/label in "subj", "group", "tree", and "cat" to numbers such that it starts from zero (e.g. data$tree = c(1,1,3,3,2,2,...) will be changed to data$tree = c(0,0,2,2,1,1,...)) and the columns will be ordered in the right way. "rt" must be provided in milliseconds. If it has decimal places it will be rounded to a whole number. `fit_rtmpt` will automatically call this function if its input is not already an `rtmpt_data` list, but it is advised to use it anyway because it provides information about the transformations of the data.

## Usage

```
to_rtmpt_data(raw_data, model)
```

## Arguments

| | |
|---|---|
| `raw_data` | `data.frame` or path to data containing columns "subj", "group", "tree", "cat", and "rt". If not provided in this order it will be reordered and unused variables will be moved to the end of the new data frame. |
| `model` | A list of the class `rtmpt_model`. |

## Value

A list of the class `rtmpt_data` containing transformed data and information about the transformation that has been done.

## Author(s)

Raphael Hartmann

## Examples

```
##############################################################################
# Detect-Guess variant of the Two-High Threshold model.
# The encoding and motor execution times are assumed to be equal for each response.
##############################################################################

mdl_2HTM <- "
# targets
do+(1-do)*g
(1-do)*(1-g)

# lures
(1-dn)*g
dn+(1-dn)*(1-g)

# do: detect old; dn: detect new; g: guess
"

model <- to_rtmpt_model(mdl_file = mdl_2HTM)

## Not run:
data <- read.table(file = "./rtmpt_data", header = TRUE)
data_list <- to_rtmpt_data(raw_data = data, model = model)

## End(Not run)
```

---

`to_rtmpt_model` *Create a model list for* `fit_rtmpt`

---

## Description

Create a model list of the class `rtmpt_model` by providing either `eqn_file` or `mdl_file`. If both are provided `mdl_file` will be used.

## Usage

```
to_rtmpt_model(eqn_file = NULL, mdl_file = NULL)
```

## Arguments

| | |
|---|---|
| `eqn_file` | Character string as shown in example 2 or path to the text file that specifies the (RT-)MPT model with standard .eqn syntax (Heck et al., 2018; Hu, 1999). E.g. `studied ; hit ; (1-do)*g` for a correct guess in the detect-guess 2HT model. |
| `mdl_file` | Character string as shown in example 1 or path to the text file that specifies the (RT-)MPT model and gives on each line the equation of one category using `+` to separate branches and `*` to separate processes (Singmann and Kellen, 2013). E.g. `do+(1-do)*g` for the category "hit" in the detect-guess 2HT model. |

## Value

A list of the class `rtmpt_model`.

## Note

Within a branch of a (RT-)MPT model it is not allowed to have the same process two or more times.

## Author(s)

Raphael Hartmann

## References

Heck, D. W., Arnold, N. R., & Arnold, D. (2018). TreeBUGS: An R package for hierarchical multinomial-processing-tree modeling. *Behavior Research Methods, 50(1)*, 264-284.

Hu, X. (1999). Multinomial processing tree models: An implementation. *Behavior Research Methods, Instruments, & Computers, 31(4)*, 689-695.

Singmann, H., & Kellen, D. (2013). MPTinR: Analysis of multinomial processing tree models in R. *Behavior Research Methods, 45(2)*, 560-575.

## See Also

- set_params
- set_resps

## Examples

```
##############################################################################################
# Detect-Guess variant of the Two-High Threshold model
#   with constant guessing and
#   suppressed process completion times for both failed detections.
# The encoding and motor execution times are assumed to be different for each response.
##############################################################################################

## 1. using the mdl syntax
mdl_2HTM <- "
# targets
do+(1-do)*g     ; 0
(1-do)*(1-g)    ; 1

# lures
(1-dn)*g        ; 0
dn+(1-dn)*(1-g) ; 1

# do: detect old; dn: detect new; g: guess

# OPTIONAL MPT CONSTRAINTS
#   set probabilities to constants:
const_prob: g=0.5

#   suppress process times:
suppress_process: dn-, do-
"

model <- to_rtmpt_model(mdl_file = mdl_2HTM)


## 2. using the eqn syntax
```

```
eqn_2HTM <- "
# CORE MPT EQN
# tree ; cat ; mpt
     0 ;   0 ; do
     0 ;   0 ; (1-do)*g
     0 ;   1 ; (1-do)*(1-g)

     1 ;   2 ; (1-dn)*g
     1 ;   3 ; dn
     1 ;   3 ; (1-dn)*(1-g)

# OPTIONAL MPT CONSTRAINTS
#   set probabilities to constants:
const_prob: g=0.5

#   suppress process times:
suppress_process: dn-, do-

#     Tree ; Cat ; Resp
resp:    0 ;   0 ;    0
resp:    0 ;   1 ;    1
resp:    1 ;   2 ;    0
resp:    1 ;   3 ;    1
# different motor execution times for old and new responses.
"

model <- to_rtmpt_model(eqn_file = eqn_2HTM)
```

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