

Package ‘cIRT’

September 27, 2025

Type Package

Title Choice Item Response Theory

Version 1.3.3

Description Jointly model the accuracy of cognitive responses and item choices within a Bayesian hierarchical framework as described by Culpepper and Balamuta (2015) <[doi:10.1007/s11336-015-9484-7](https://doi.org/10.1007/s11336-015-9484-7)>. In addition, the package contains the datasets used within the analysis of the paper.

License GPL (>= 2)

URL <https://tmsalab.github.io/cIRT/>, <https://github.com/tmsalab/cIRT>

BugReports <https://github.com/tmsalab/cIRT/issues>

Depends R (>= 4.3.0)

Imports Rcpp (>= 1.1.0)

LinkingTo Rcpp, RcppArmadillo (>= 15.0.2-2)

Suggests knitr, rmarkdown, covr

LazyData true

Encoding UTF-8

RoxygenNote 7.3.3

Language en-US

VignetteBuilder knitr

NeedsCompilation yes

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Repository CRAN

Date/Publication 2025-09-27 05:20:02 UTC

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cIRT-package

cIRT: Choice Item Response Theory

Description

Jointly model the accuracy of cognitive responses and item choices within a Bayesian hierarchical framework as described by Culpepper and Balamuta (2015) [doi:10.1007/s1133601594847](https://doi.org/10.1007/s1133601594847). In addition, the package contains the datasets used within the analysis of the paper.

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See Also

Useful links:

- <https://tmsalab.github.io/cIRT/>
- <https://github.com/tmsalab/cIRT>
- Report bugs at <https://github.com/tmsalab/cIRT/issues>

center_matrix	<i>Center a Matrix</i>
---------------	------------------------

Description

Obtains the mean of each column of the matrix and subtracts it from the given matrix in a centering operation.

Usage

```
center_matrix(x)
```

Arguments

x A matrix with any dimensions

Details

The application of this function to a matrix mimics the use of a centering matrix given by:

$$C_n = I_n - \frac{1}{n}11^T$$

Value

A matrix with the same dimensions of X that has been centered.

Author(s)

James Joseph Balamuta

See Also

[cIRT\(\)](#)

Examples

```
nobs = 500
nvars = 20
x = matrix(rnorm(nobs * nvars), nrow = nobs, ncol = nvars)
r_centered = scale(x)
arma_centered1 = center_matrix(x)
```

 choice_matrix

Choice Matrix Data

Description

This data set contains the subject's choices and point values for the difficult questions.

Usage

choice_matrix

Format

A data frame with 3780 observations on the following 5 variables.

subject_id Research Participant Subject ID. There are 102 IDs and each ID has 15 observations.

hard_q_id The item ID of the hard question assigned to the student (16-30)

easy_q_id The item ID of the easy question assigned to the student (1-15)

choose_hard_q Selected either: Difficult Question (1) or Easy Question (0)

high_value Range of values associated with Difficult Question that span from 12 to 16, repeated three times per subject

low_value Range of values associated with Easy Question that span from 4 to 6, repeated five times per subject

is_correct_choice Did the user select an item that was answered correctly?

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

Source

Choice38 Experiment at UIUC during Spring 2014 - Fall 2014

 cIRT

Generic Implementation of Choice IRT MCMC

Description

Builds a model using MCMC

Usage

```
cIRT(
  subject_ids,
  fixed_effects,
  B_elem_plus1,
  rv_effects,
  trial_matrix,
  choices_nk,
  burnit,
  chain_length = 10000L
)
```

Arguments

<code>subject_ids</code>	A vector that contains subject IDs for each line of data in the choice vector (e.g. For 1 subject that made 5 choices, we would have the number 1 appear five times consecutively.)
<code>fixed_effects</code>	A matrix with $NK \times P1$ dimensions that acts as the design matrix for terms WITHOUT theta.
<code>B_elem_plus1</code>	A $V[[1]]$ dimensional column vector indicating which ζ_i relate to θ_i .
<code>rv_effects</code>	A matrix with $NK \times V$ dimensions for random effects design matrix.
<code>trial_matrix</code>	A matrix with $N \times J$ dimensions, where J denotes the number of items presented. The matrix MUST contain only 1's and 0's.
<code>choices_nk</code>	A vector with NK length that contains the choice value e.g. 0 or 1.
<code>burnit</code>	An int that describes how many MCMC draws should be discarded.
<code>chain_length</code>	An int that controls how many MCMC draws there are. (> 0)

Value

A list that contains:

`as` A matrix of dimension $\text{chain_length} \times J$

`bs` A matrix of dimension $\text{chain_length} \times J$

`gs` A matrix of dimension $\text{chain_length} \times P_1$

`Sigma_zeta_inv` An array of dimension $V \times V \times \text{chain_length}$

`betas` A matrix of dimension $\text{chain_length} \times P_2$

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[TwoPLChoicemcmc\(\)](#), [probitHLM\(\)](#), [center_matrix\(\)](#), [rmvnorm\(\)](#), [rwishart\(\)](#), and [riwishart\(\)](#)

Examples

```

## Not run:
# Variables
# Y = trial matrix
# C = KN vector of binary choices
# N = #of subjects
# J = # of items
# K= # of choices
# atrue = true item discriminations
# btrue = true item locations
# thetatru = true thetas/latent performance
# gamma = fixed effects coefficients
# Sig = random-effects variance-covariance
# subid = id variable for subjects

# Load the Package
library(cIRT)

# Load the Data
data(trial_matrix)
data(choice_matrix)

# Thurstone design matrices
all_nopractice = subset(all_data_trials, experiment_loop.thisN > -1)
hard_items = choice_matrix$hard_q_id
easy_items = choice_matrix$easy_q_id

D_easy = model.matrix( ~ -1 + factor(easy_items))
D_hard = -1 * model.matrix( ~ -1 + factor(hard_items))[, -c(5, 10, 15)]

# Defining effect-coded contrasts
high_contrasts = rbind(-1, diag(4))
rownames(high_contrasts) = 12:16
low_contrasts = rbind(-1, diag(2))
rownames(low_contrasts) = 4:6

# Creating high & low factors
high = factor(choice_matrix[, 'high_value'])
low = factor(choice_matrix[, 'low_value'])
contrasts(high) = high_contrasts
contrasts(low) = low_contrasts

fixed_effects = model.matrix( ~ high + low)
fixed_effects_base = fixed_effects[, 1]
fixed_effects_int = model.matrix( ~ high * low)

# Model with Thurstone D Matrix
system.time({
  out_model_thurstone = cIRT(
    choice_matrix[, 'subject_id'],
    cbind(fixed_effects[, -1], D_easy, D_hard),

```

```

    c(1:ncol(fixed_effects)),
    as.matrix(fixed_effects),
    as.matrix(trial_matrix),
    choice_matrix[, 'choose_hard_q'],
    20000,
    25000
  )
})

vlabels_thurstone = colnames(cbind(fixed_effects[, -1], D_easy, D_hard))
G_thurstone = t(apply(
  out_model_thurstone$gs0,
  2,
  FUN = quantile,
  probs = c(.5, .025, .975)
))

rownames(G_thurstone) = vlabels_thurstone
B_thurstone = t(apply(
  out_model_thurstone$beta,
  2,
  FUN = quantile,
  probs = c(.5, 0.025, .975)
))

rownames(B_thurstone) = colnames(fixed_effects)

S_thurstone = solve(
  apply(out_model_thurstone$Sigma_zeta_inv, c(1, 2), FUN = mean)
)

inv_sd = diag(1 / sqrt(diag(solve(
  apply(out_model_thurstone$Sigma_zeta_inv, c(1, 2),
    FUN = mean)
))))

inv_sd ** S_thurstone ** inv_sd
apply(out_model_thurstone$as, 2, FUN = mean)
apply(out_model_thurstone$bs, 2, FUN = mean)

## End(Not run)

```

direct_sum

Direct Sum of Matrices

Description

Computes the direct sum of all matrices passed in via the list.

Usage

```
direct_sum(x)
```

Arguments

`x` A field<matrix> or list containing matrices

Details

Consider matrix A ($M \times N$) and B ($K \times P$). A direct sum is a diagonal matrix $A(+)B$ with dimensions $(m + k) \times (n + p)$.

Value

Matrix containing the direct sum of all matrices in the list.

Author(s)

James Joseph Balamuta

Examples

```
x = list(matrix(0, nrow = 5, ncol = 3),
         matrix(1, nrow = 5, ncol = 3))
direct_sum(x)
```

```
x = list(matrix(rnorm(15), nrow = 5, ncol = 3),
         matrix(rnorm(30), nrow = 5, ncol = 6),
         matrix(rnorm(18), nrow = 2, ncol = 9))
direct_sum(x)
```

Generate_Choice

Generate Observed Data from choice model

Description

Generates observed cognitive and choice data from the IRT-Thurstone model.

Usage

```
Generate_Choice(
  N,
  J,
  K,
  theta,
  as,
  bs,
  zeta,
```

```

    gamma,
    X,
    W,
    subject_ids,
    unique_subject_ids
  )

```

Arguments

N	An integer for the number of observations.
J	An integer for the number of items.
K	An integer for the number of paired comparisons.
theta	A vector of latent cognitive variables.
as	A vector of length J with item discriminations.
bs	A vector of length J with item locations.
zeta	A matrix with dimensions N x V containing random parameter estimates.
gamma	A vector with dimensions P x 1 containing fixed parameter estimates, where $P = P_1 + P_2$
X	A matrix with dimensions N*K x P_1 containing fixed effect design matrix without theta.
W	A matrix with dimensions N*K x V containing random effect variables.
subject_ids	A vector with length NK x 1 containing subject-choice IDs.
unique_subject_ids	A vector with length N x 1 containing unique subject IDs.

Value

A list that contains:

Y A matrix of dimension N by J

C A vector of length NK

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

payout_matrix	<i>Payout Matrix Data</i>
---------------	---------------------------

Description

This data set contains the payout information for each subject.

Usage

```
payout_matrix
```

Format

A data frame with 252 observations on the following 4 variables.

Participant Subject ID

cum_sum Sum of all payouts

num_correct_choices Total number of correct choices (out of 15)

num_correct_trials Total number of correct trials (out of 30)

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

Source

Choice38 Experiment at UIUC during Spring 2014 - Fall 2014

probitHLM	<i>Probit Hierarchical Level Model</i>
-----------	----------------------------------------

Description

Performs modeling procedure for a Probit Hierarchical Level Model.

Usage

```
probitHLM(  
  unique_subject_ids,  
  subject_ids,  
  choices_nk,  
  fixed_effects_design,  
  rv_effects_design,  
  B_elem_plus1,  
  gamma,
```

```

    beta,
    theta,
    zeta_rv,
    WtW,
    Z_c,
    Wzeta_0,
    inv_Sigma_gamma,
    mu_gamma,
    Sigma_zeta_inv,
    S0,
    mu_beta,
    sigma_beta_inv
)

```

Arguments

unique_subject_ids A vector with length $N \times 1$ containing unique subject IDs.

subject_ids A vector with length $N \times K \times 1$ containing subject IDs.

choices_nk A vector with length $N \times K \times 1$ containing subject choices.

fixed_effects_design A matrix with dimensions $N \times K \times P$ containing fixed effect variables.

rv_effects_design A matrix with dimensions $N \times K \times V$ containing random effect variables.

B_elem_plus1 A $V[[1]]$ dimensional column vector indicating which zeta_i relate to theta_i.

gamma A vector with dimensions $P_1 \times 1$ containing fixed parameter estimates.

beta A vector with dimensions $P_2 \times 1$ containing random parameter estimates.

theta A vector with dimensions $N \times 1$ containing subject understanding estimates.

zeta_rv A matrix with dimensions $N \times V$ containing random parameter estimates.

WtW A field<matrix> $P \times P \times N$ contains the caching for direct sum.

Z_c A vector with dimensions $N \times K \times 1$

Wzeta_0 A vector with dimensions $N \times K \times 1$

inv_Sigma_gamma A matrix with dimensions $P \times P$ that is the prior inverse sigma matrix for gamma.

mu_gamma A vector with length $P \times 1$ that is the prior mean vector for gamma.

Sigma_zeta_inv A matrix with dimensions $V \times V$ that is the prior inverse sigma matrix for zeta.

S0 A matrix with dimensions $V \times V$ that is the prior sigma matrix for zeta.

mu_beta A vector with dimensions $P_2 \times 1$, that is the mean of beta.

sigma_beta_inv A matrix with dimensions $P_2 \times P_2$, that is the inverse sigma matrix of beta.

Details

The function is implemented to decrease the amount of vectorizations necessary.

Value

A list that contains:

zeta_1 A vector of length N

sigma_zeta_inv_1 A matrix of dimensions V x V

gamma_1 A vector of length P

beta_1 A vector of length V

B A matrix of length V

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[rwishart\(\)](#) and [TwoPLChoicemcmc\(\)](#)

riwishart

Generate Random Inverse Wishart Distribution

Description

Creates a random inverse wishart distribution when given degrees of freedom and a sigma matrix.

Usage

```
riwishart(df, S)
```

Arguments

df An integer that represents the degrees of freedom. (> 0)

S A matrix with dimensions m x m that provides Sigma, the covariance matrix.

Value

A matrix that is an inverse wishart distribution.

Author(s)

James Joseph Balamuta

See Also

[rwishart\(\)](#) and [TwoPLChoicemcmc\(\)](#)

Examples

```
#Call with the following data:  
riwishart(3, diag(2))
```

`rmvnorm`*Generate Random Multivariate Normal Distribution*

Description

Creates a random Multivariate Normal when given number of obs, mean, and sigma.

Usage

```
rmvnorm(n, mu, S)
```

Arguments

`n` An integer, which gives the number of observations. (> 0)
`mu` A vector length `m` that represents the means of the normals.
`S` A matrix with dimensions `m x m` that provides Sigma, the covariance matrix.

Value

A matrix that is a Multivariate Normal distribution.

Author(s)

James Joseph Balamuta

See Also

[TwoPLChoicemcmc\(\)](#) and [probitHLM\(\)](#)

Examples

```
# Call with the following data:  
rmvnorm(2, c(0,0), diag(2))
```

`rwishart`*Generate Random Wishart Distribution*

Description

Creates a random wishart distribution when given degrees of freedom and a sigma matrix.

Usage

```
rwishart(df, S)
```

Arguments

- `df` An integer, which gives the degrees of freedom of the Wishart. (> 0)
- `S` A matrix with dimensions $m \times m$ that provides Sigma, the covariance matrix.

Value

A matrix that is a Wishart distribution, aka the sample covariance matrix of a Multivariate Normal Distribution

Author(s)

James Joseph Balamuta

See Also

[riwishart\(\)](#) and [probitHLM\(\)](#)

Examples

```
# Call with the following data:
rwishart(3, diag(2))

# Validation
set.seed(1337)
S = toeplitz((10:1)/10)
n = 10000
o = array(dim = c(10,10,n))
for(i in 1:n){
o[, ,i] = rwishart(20, S)
}
mR = apply(o, 1:2, mean)
Va = 20*(S^2 + tcrossprod(diag(S)))
vR = apply(o, 1:2, var)
stopifnot(all.equal(vR, Va, tolerance = 1/16))
```

survey_data

Survey Data

Description

This data set contains the subject's responses survey questions administered using Choice38.

Usage

survey_data

Format

A data frame with 102 observations on the following 2 variables.

id Subject's Assigned Research ID

sex Subject's sex:

- Male
- Female

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

Source

Choice38 Experiment at UIUC during Spring 2014 - Fall 2014

Total_Tabulate	<i>Calculate Tabulated Total Scores</i>
----------------	-----------------------------------------

Description

Internal function to -2LL

Usage

Total_Tabulate(N, J, Y)

Arguments

N An integer, which gives the number of observations. (> 0)
J An integer, which gives the number of items. (> 0)
Y A N by J matrix of item responses.

Value

A vector of tabulated total scores.

Author(s)

Steven Andrew Culpepper

`trial_matrix`*Trial Matrix Data*

Description

This data set contains the subject's responses to items. Correct answers are denoted by 1 and incorrect answers are denoted by 0.

Usage`trial_matrix`**Format**

A data frame with 252 observations on the following 30 variables.

- t1 Subject's Response to Item 1.
- t2 Subject's Response to Item 2.
- t3 Subject's Response to Item 3.
- t4 Subject's Response to Item 4.
- t5 Subject's Response to Item 5.
- t6 Subject's Response to Item 6.
- t7 Subject's Response to Item 7.
- t8 Subject's Response to Item 8.
- t9 Subject's Response to Item 9.
- t10 Subject's Response to Item 10.
- t11 Subject's Response to Item 11.
- t12 Subject's Response to Item 12.
- t13 Subject's Response to Item 13.
- t14 Subject's Response to Item 14.
- t15 Subject's Response to Item 15.
- t16 Subject's Response to Item 16.
- t17 Subject's Response to Item 17.
- t18 Subject's Response to Item 18.
- t19 Subject's Response to Item 19.
- t20 Subject's Response to Item 20.
- t21 Subject's Response to Item 21.
- t22 Subject's Response to Item 22.
- t23 Subject's Response to Item 23.
- t24 Subject's Response to Item 24.

- t25 Subject's Response to Item 25.
- t26 Subject's Response to Item 26.
- t27 Subject's Response to Item 27.
- t28 Subject's Response to Item 28.
- t29 Subject's Response to Item 29.
- t30 Subject's Response to Item 30.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

Source

Choice38 Experiment at UIUC during Spring 2014 - Fall 2014

TwoPLChoicemcmc

Two Parameter Choice IRT Model MCMC

Description

Performs an MCMC routine for a two parameter IRT Model using Choice Data

Usage

```
TwoPLChoicemcmc(  
  unique_subject_ids,  
  subject_ids,  
  choices_nk,  
  fixed_effects,  
  B,  
  rv_effects_design,  
  gamma,  
  beta,  
  zeta_rv,  
  Sigma_zeta_inv,  
  Y,  
  theta0,  
  a0,  
  b0,  
  mu_xi0,  
  Sig_xi0  
)
```

Arguments

<code>unique_subject_ids</code>	A vector with length $N \times 1$ containing unique subject IDs.
<code>subject_ids</code>	A vector with length $NK \times 1$ containing subject IDs.
<code>choices_nk</code>	A vector with length $NK \times 1$ containing subject choices.
<code>fixed_effects</code>	A matrix with dimensions $NK \times P_1$ containing fixed effect design matrix without theta.
<code>B</code>	A V dimensional column vector relating θ_i and ζ_i .
<code>rv_effects_design</code>	A matrix with dimensions $NK \times V$ containing random effect variables.
<code>gamma</code>	A vector with dimensions $P \times 1$ containing fixed parameter estimates, where $P = P_1 + P_2$
<code>beta</code>	A vector with dimensions P_2 containing random parameter estimates.
<code>zeta_rv</code>	A matrix with dimensions $N \times V$ containing random parameter estimates.
<code>Sigma_zeta_inv</code>	A matrix with dimensions $P_2 \times P_2$.
<code>Y</code>	A matrix of dimensions $N \times J$ for Dichotomous item responses
<code>theta0</code>	A vector of length $N \times 1$ for latent theta.
<code>a0</code>	A vector of length J for item discriminations.
<code>b0</code>	A vector of length J for item locations.
<code>mu_xi0</code>	A vector of dimension 2 (i.e. $c(0,1)$) that is a prior for item parameter means.
<code>Sig_xi0</code>	A matrix of dimension 2×2 (i.e. $\text{diag}(2)$) that is a prior for item parameter vc matrix.

Value

A list that contains:

<code>ai1</code>	A vector of length J
<code>bi1</code>	A vector of length J
<code>theta1</code>	A vector of length N
<code>Z_c</code>	A matrix of length NK
<code>Wzeta_0</code>	A matrix of length NK

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[cIRT\(\)](#), [rmvnorm\(\)](#), and [riwishart\(\)](#)

Examples

```
## Not run:  
# Call with the following data:  
TwoPLChoicemcmc(cogDAT, theta0, a0, b0, mu_xi0, Sig_xi0)  
  
## End(Not run)
```

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