Package 'cIRT'

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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>. 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

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Author Steven Andrew Culpepper [aut, cph] (<https://orcid.org/0000-0003-4226-6176>), James Joseph Balamuta [aut, cph, cre] (<https://orcid.org/0000-0003-2826-8458>)

Maintainer James Joseph Balamuta <balamut2@illinois.edu>

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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/s11336-015-9484-7>. In addition, the package contains the datasets used within the analysis of the paper.

Author(s)

Maintainer: James Joseph Balamuta <balamut2@illinois.edu> (ORCID) [copyright holder]

Authors:

- Steven Andrew Culpepper <sculpepp@illinois.edu> (ORCID) [copyright holder]

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` *Center a Matrix*

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:

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

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

subject_ids	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.)
fixed_effects	A matrix with NK x P1 dimensions that acts as the design matrix for terms WITHOUT theta.
B_elem_plus1	A V[[1]] dimensional column vector indicating which zeta_i relate to theta_i.
rv_effects	A matrix with NK x V dimensions for random effects design matrix.
trial_matrix	A matrix with N x J dimensions, where J denotes the number of items presented. The matrix MUST contain only 1's and 0's.
choices_nk	A vector with NK length that contains the choice value e.g. 0 or 1.
burnit	An int that describes how many MCMC draws should be discarded.
chain_length	An int that controls how many MCMC draws there are. (> 0)

Value

A list that contains:

as A matrix of dimension chain_length x J

bs A matrix of dimension chain_length x J

gs A matrix of dimension chain_length x P_1

Sigma_zeta_inv An array of dimension V x V x chain_length

betas A matrix of dimension chain_length x 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 matix
# C = KN vector of binary choices
# N = #of subjects
# J = # of items
# K= # of choices
# atrue = true item discriminations
# btrue = true item locations
# thetatrue = 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 $(m + k)x(n + p)$.

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 *Payout Matrix Data*

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 *Probit Hierarchical Level Model*

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 x 1 containing unique subject IDs.
`subject_ids`	A `vector` with length N*K x 1 containing subject IDs.
`choices_nk`	A `vector` with length N*K x 1 containing subject choices.
`fixed_effects_design`	A `matrix` with dimensions N*K x P containing fixed effect variables.
`rv_effects_design`	A `matrix` with dimensions N*K x 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 x 1 containing fixed parameter estimates.
`beta`	A `vector` with dimensions P_2 x 1 containing random parameter estimates.
`theta`	A `vector` with dimensions N x 1 containing subject understanding estimates.
`zeta_rv`	A `matrix` with dimensions N x V containing random parameter estimates.
`WtW`	A `field<matrix>` P x P x N contains the caching for direct sum.
`Z_c`	A `vector` with dimensions N*K x 1
`Wzeta_0`	A `vector` with dimensions N*K x 1
`inv_Sigma_gamma`	A `matrix` with dimensions P x P that is the prior inverse sigma matrix for gamma.
`mu_gamma`	A `vector` with length P x 1 that is the prior mean vector for gamma.
`Sigma_zeta_inv`	A `matrix` with dimensions V x V that is the prior inverse sigma matrix for zeta.
`S0`	A `matrix` with dimensions V x V that is the prior sigma matrix for zeta.
`mu_beta`	A `vector` with dimensions P_2 x 1, that is the mean of beta.
`sigma_beta_inv`	A `matrix` with dimensions P_2 x 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 x 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 *Calculate Tabulated Total Scores*

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

`unique_subject_ids`	A `vector` with length $N \times 1$ containing unique subject IDs.
`subject_ids`	A `vector` with length $NK \times 1$ containing subject IDs.
`choices_nk`	A `vector` with length $NK \times 1$ containing subject choices.
`fixed_effects`	A `matrix` with dimensions $NK \times P_1$ containing fixed effect design matrix without theta.
`B`	A V dimensional column `vector` relating θ_i and ζ_i.
`rv_effects_design`	A `matrix` with dimensions $NK \times V$ containing random effect variables.
`gamma`	A `vector` with dimensions $P \times 1$ containing fixed parameter estimates, where $P = P_1 + P_2$
`beta`	A `vector` with dimensions P_2 containing random parameter estimates.
`zeta_rv`	A `matrix` with dimensions $N \times V$ containing random parameter estimates.
`Sigma_zeta_inv`	A `matrix` with dimensions $P_2 \times P_2$.
`Y`	A `matrix` of dimensions $N \times J$ for Dichotomous item responses
`theta0`	A `vector` of length $N \times 1$ for latent theta.
`a0`	A `vector` of length J for item discriminations.
`b0`	A `vector` of length J for item locations.
`mu_xi0`	A `vector` of dimension 2 (i.e. c(0,1)) that is a prior for item parameter means.
`Sig_xi0`	A `matrix` of dimension 2x2 (i.e. diag(2)) that is a prior for item parameter vc matrix.

Value

A `list` that contains:

`ai1` A `vector` of length J

`bi1` A `vector` of length J

`theta1` A `vector` of length N

`Z_c` A `matrix` of length NK

`Wzeta_0` 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)
```

Index