

Package ‘simcdm’

March 10, 2019

Type Package

Title Simulate Cognitive Diagnostic Model ('CDM') Data

Version 0.1.1

Description Provides efficient R and 'C++' routines to simulate cognitive diagnostic model data for Deterministic Input, Noisy ``And" Gate ('DINA') and reduced Reparameterized Unified Model ('rRUM') from Culpepper and Hudson (2017) <doi: 10.1177/0146621617707511>, Culpepper (2015) <doi:10.3102/1076998615595403>, and de la Torre (2009) <doi:10.3102/1076998607309474>.

Depends R (>= 3.4.0)

Imports Rcpp (>= 1.0.0)

LinkingTo Rcpp, RcppArmadillo (>= 0.9.200)

URL <https://github.com/tmsalab/simcdm>

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

License GPL (>= 2)

RoxygenNote 6.1.1

Encoding UTF-8

Suggests testthat, covr, knitr, rmarkdown

VignetteBuilder knitr

NeedsCompilation yes

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Repository CRAN

Date/Publication 2019-03-10 06:00:03 UTC

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simcdm-package	<i>simcdm: Simulate Cognitive Diagnostic Model ('CDM') Data</i>
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Description

Provides efficient R and 'C++' routines to simulate cognitive diagnostic model data for Deterministic Input, Noisy "And" Gate ('DINA') and reduced Reparameterized Unified Model ('rRUM') from Culpepper and Hudson (2017) <doi: 10.1177/0146621617707511>, Culpepper (2015) <doi:10.3102/1076998615595403>, and de la Torre (2009) <doi:10.3102/1076998607309474>.

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See Also

Useful links:

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

attribute_bijection *Constructs Unique Attribute Pattern Map*

Description

Computes the powers of 2 from 0 up to $K - 1$ for K -dimensional attribute pattern.

Usage

```
attribute_bijection(K)
```

Arguments

K Number of Attributes.

Value

A vec with length K detailing the power's of 2.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::attribute_inv_bijection\(\)](#)

Examples

```
## Construct an attribute bijection ----
birect = attribute_bijection(3)
```

attribute_classes *Simulate all the Latent Attribute Profile α_c in Matrix form*

Description

Generate the $\alpha_c = (\alpha_{c1}, \dots, \alpha_{cK})'$ attribute profile matrix for members of class c such that α_{ck} is 1 if members of class c possess skill k and zero otherwise.

Usage

```
attribute_classes(K)
```

Arguments

K Number of Attributes

Value

A 2^K by K matrix of latent classes corresponding to entry c of p_i based upon mastery and non-mastery of the K skills.

Author(s)

James Joseph Balamuta and Steven Andrew Culpepper

See Also

[simcdm::sim_subject_attributes\(\)](#) and [simcdm::attribute_inv_bijection\(\)](#)

Examples

```
## Simulate Attribute Class Matrix ----

# Define number of attributes
K = 3

# Generate an Latent Attribute Profile (Alpha) Matrix
alphas = attribute_classes(K)
```

```
attribute_inv_bijection
```

Perform an Inverse Bijection of an Integer to Attribute Pattern

Description

Convert an integer between 0 and 2^{K-1} to K -dimensional attribute pattern.

Usage

```
attribute_inv_bijection(K, CL)
```

Arguments

K	Number of Attributes.
CL	An integer between 0 and 2^{K-1}

Value

A K -dimensional vector with an attribute pattern corresponding to CL.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::attribute_bijection\(\)](#)

Examples

```
## Construct an attribute inversion bijection ----
inv_biject1 = attribute_inv_bijection(5, 1)
inv_biject2 = attribute_inv_bijection(5, 2)
```

sim_dina_attributes *Simulate a DINA Model's η Matrix*

Description

Generates a DINA model's η matrix based on alphas and the **Q** matrix.

Usage

```
sim_dina_attributes(alphas, Q)
```

Arguments

alphas	A N by K matrix of latent attributes.
Q	A J by K matrix indicating which skills are required for which items.

Value

The η matrix with dimensions $N \times J$ under the DINA model.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::sim_dina_class\(\)](#) and [simcdm::sim_dina_items\(\)](#)

Examples

```
N = 200
K = 5
J = 30
delta0 = rep(1, 2 ^ K)

# Creating Q matrix
Q = matrix(rep(diag(K), 2), 2 * K, K, byrow = TRUE)
for (mm in 2:K) {
  temp = combn(seq_len(K), m = mm)
```

```

    tempmat = matrix(0, ncol(temp), K)
    for (j in seq_len(ncol(temp)))
      tempmat[j, temp[, j]] = 1
    Q = rbind(Q, tempmat)
  }
  Q = Q[seq_len(J), ]

# Setting item parameters and generating attribute profiles
ss = gs = rep(.2, J)
PIs = rep(1 / (2 ^ K), 2 ^ K)
CLs = c((1:(2 ^ K)) %% rmultinom(n = N, size = 1, prob = PIs))

# Defining matrix of possible attribute profiles
As = rep(0, K)
for (j in seq_len(K)) {
  temp = combn(1:K, m = j)
  tempmat = matrix(0, ncol(temp), K)
  for (j in seq_len(ncol(temp)))
    tempmat[j, temp[, j]] = 1
  As = rbind(As, tempmat)
}
As = as.matrix(As)

# Sample true attribute profiles
Alphas = As[CLs, ]

# Simulate item data under DINA model
dina_items = sim_dina_items(Alphas, Q, ss, gs)

# Simulate attribute data under DINA model
dina_attributes = sim_dina_attributes(Alphas, Q)

```

 sim_dina_class

Simulate Binary Responses for a DINA Model

Description

Generate the dichotomous item matrix for a DINA Model.

Usage

```
sim_dina_class(N, J, CLASS, ETA, gs, ss)
```

Arguments

N	Number of Observations
J	Number of Assessment Items
CLASS	Does the individual possess all the necessary attributes?
ETA	η Matrix containing indicators.

gs	A vec describing the probability of guessing or the probability subject correctly answers item j when at least one attribute is lacking.
ss	A vec describing the probability of slipping or the probability of an incorrect response for individuals with all of the required attributes

Value

A dichotomous item matrix with dimensions $N \times J$.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::sim_dina_attributes\(\)](#) and [simcdm::sim_dina_items\(\)](#)

Examples

```
# Set
N      = 100
rho    = 0
K      = 3

# Fixed Number of Assessment Items for Q
J = 18

# Specify Q
qbj = c(4, 2, 1, 4, 2, 1, 4, 2, 1, 6, 5, 3, 6, 5, 3, 7, 7, 7)

# Fill Q Matrix
Q = matrix(, J, K)
for (j in seq_len(J)) {
  Q[j,] = attribute_inv_bijection(K, qbj[j])
}

# Item parm vals
ss = gs = rep(.2, J)

# Generating attribute classes depending on correlation
if (rho == 0) {
  PIs = rep(1 / (2 ^ K), 2 ^ K)
  CLs = c(seq_len(2 ^ K) %%% rmultinom(n = N, size = 1, prob = PIs)) - 1
}

if (rho > 0) {
  Z = matrix(rnorm(N * K), N, K)
  Sig = matrix(rho, K, K)
  diag(Sig) = 1
  X = Z %%% chol(Sig)
  thvals = matrix(rep(0, K), N, K, byrow = T)
  Alphas = 1 * (X > thvals)
```

```

  CLs = Alphas %*% attribute_bijection(K)
}

# Simulate data under DINA model
ETA = sim_eta_matrix(K, J, Q)
Y_sim = sim_dina_class(N, J, CLs, ETA, gs, ss)

```

sim_dina_items

Simulation Responses from the DINA model

Description

Sample responses from the DINA model for given attribute profiles, Q matrix, and item parameters. Returns a matrix of dichotomous responses generated under DINA model.

Usage

```
sim_dina_items(alphas, Q, ss, gs)
```

Arguments

alphas	A N by K matrix of latent attributes.
Q	A J by K matrix indicating which skills are required for which items.
ss	A J vector of item slipping parameters.
gs	A J vector of item guessing parameters.

Value

A N by J matrix of responses from the DINA model.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::sim_dina_class\(\)](#) and [simcdm::sim_dina_attributes\(\)](#)

Examples

```

N = 200
K = 5
J = 30
delta0 = rep(1, 2 ^ K)

# Creating Q matrix
Q = matrix(rep(diag(K), 2), 2 * K, K, byrow = TRUE)
for (mm in 2:K) {

```



```

temp = combn(seq_len(K), m = mm)
tempmat = matrix(0, ncol(temp), K)
for (j in seq_len(ncol(temp)))
  tempmat[j, temp[, j]] = 1
Q = rbind(Q, tempmat)
}
Q = Q[seq_len(J), ]

# Setting item parameters and generating attribute profiles
ss = gs = rep(.2, J)
PIs = rep(1 / (2 ^ K), 2 ^ K)
CLs = c((1:(2 ^ K)) %% rmultinom(n = N, size = 1, prob = PIs))

# Defining matrix of possible attribute profiles
As = rep(0, K)
for (j in seq_len(K)) {
  temp = combn(1:K, m = j)
  tempmat = matrix(0, ncol(temp), K)
  for (j in seq_len(ncol(temp)))
    tempmat[j, temp[, j]] = 1
  As = rbind(As, tempmat)
}
As = as.matrix(As)

# Sample true attribute profiles
Alphas = As[CLs, ]

# Simulate item data under DINA model
dina_items = sim_dina_items(Alphas, Q, ss, gs)

# Simulate attribute data under DINA model
dina_attributes = sim_dina_attributes(Alphas, Q)

```

sim_eta_matrix *Generate ideal response η Matrix*

Description

Creates the ideal response matrix for each trait

Usage

```
sim_eta_matrix(K, J, Q)
```

Arguments

K	Number of Attribute Levels
J	Number of Assessment Items
Q	Q Matrix with dimensions $K \times J$.

Value

A mat with dimensions $J \times 2^K$.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::sim_q_matrix\(\)](#), [simcdm::attribute_bijection\(\)](#), and [simcdm::attribute_inv_bijection\(\)](#)

Examples

```
## Simulation Settings ----

# Fixed Number of Assessment Items for Q
J = 18

# Fixed Number of Attributes for Q
K = 3

## Pre-specified configuration ----

# Specify Q
qbj = c(4, 2, 1, 4, 2, 1, 4, 2, 1, 6, 5, 3, 6, 5, 3, 7, 7, 7)

# Fill Q Matrix
Q = matrix(, J, K)
for (j in seq_len(J)) {
  Q[j,] = attribute_inv_bijection(K, qbj[j])
}

# Create an eta matrix
ETA = sim_eta_matrix(K, J, Q)

## Random generation of Q matrix with ETA matrix ----

# Construct a random q matrix
Q_sim = sim_q_matrix(J, K)

# Generate the eta matrix
ETA_gen = sim_eta_matrix(K, J, Q_sim)
```

sim_q_matrix

Generate a Random Identifiable Q Matrix

Description

Simulates a Q matrix containing three identity matrices after a row permutation that is identifiable.

Usage

```
sim_q_matrix(J, K)
```

Arguments

J	Number of Items
K	Number of Attributes

Value

A dichotomous matrix for Q.

Author(s)

Steven Andrew Culpepper and James Joseph Balamuta

See Also

[simcdm::attribute_bijection\(\)](#) and [simcdm::attribute_inv_bijection\(\)](#)

Examples

```
## Simulate identifiable Q matrices ----  
  
# 7 items and 2 attributes  
q_matrix_j7_k2 = sim_q_matrix(7, 2)  
  
# 10 items and 3 attributes  
q_matrix_j10_k3 = sim_q_matrix(10, 3)
```

sim_rrum_items	<i>Generate data from the rRUM</i>
----------------	------------------------------------

Description

Randomly generate response data according to the reduced Reparameterized Unified Model (rRUM).

Usage

```
sim_rrum_items(Q, rstar, pistar, alpha)
```

Arguments

Q	A matrix with J rows and K columns indicating which attributes are required to answer each of the items, where J represents the number of items and K the number of attributes. An entry of 1 indicates attribute k is required to answer item j . An entry of one indicates attribute k is not required.
rstar	A matrix a matrix with J rows and K columns indicating the penalties for failing to have each of the required attributes, where J represents the number of items and K the number of attributes. rstar and Q must share the same 0 entries.
pistar	A vector of length J indicating the probabilities of answering each item correctly for individuals who do not lack any required attribute, where J represents the number of items.
alpha	A matrix with N rows and K columns indicating the subjects attribute acquisition, where K represents the number of attributes. An entry of 1 indicates individual i has attained attribute k . An entry of 0 indicates the attribute has not been attained.

Value

Y A matrix with N rows and J columns indicating the individuals' responses to each of the items, where J represents the number of items.

Author(s)

Steven Andrew Culpepper, Aaron Hudson, and James Joseph Balamuta

References

Culpepper, S. A. & Hudson, A. (In Press). An improved strategy for Bayesian estimation of the reduced reparameterized unified model. *Applied Psychological Measurement*.

Hudson, A., Culpepper, S. A., & Douglas, J. (2016, July). Bayesian estimation of the generalized NIDA model with Gibbs sampling. Paper presented at the annual International Meeting of the Psychometric Society, Asheville, North Carolina.

Examples

```
# Set seed for reproducibility
set.seed(217)

# Define Simulation Parameters
N = 1000 # number of individuals
J = 6 # number of items
K = 2 # number of attributes

# Matrix where rows represent attribute classes
As = attribute_classes(K)

# Latent Class probabilities
pis = c(.1, .2, .3, .4)
```

```

# Q Matrix
Q = rbind(c(1, 0),
          c(0, 1),
          c(1, 0),
          c(0, 1),
          c(1, 1),
          c(1, 1)
          )

# The probabilities of answering each item correctly for individuals
# who do not lack any required attribute
pistar = rep(.9, J)

# Penalties for failing to have each of the required attributes
rstar = .5 * Q

# Randomized alpha profiles
alpha = As[sample(1:(K ^ 2), N, replace = TRUE, pis),]

# Simulate data
rrum_items = sim_rrum_items(Q, rstar, pistar, alpha)

```

sim_subject_attributes

Simulate Subject Latent Attribute Profiles α_c

Description

Generate a sample from the $\alpha_c = (\alpha_{c1}, \dots, \alpha_{cK})'$ attribute profile matrix for members of class c such that α_{ck} is 1 if members of class c possess skill k and zero otherwise.

Usage

```
sim_subject_attributes(N, K, probs = NULL)
```

Arguments

N	Number of Observations
K	Number of Skills
probs	A vector of probabilities that sum to 1.

Value

A N by K matrix of latent classes corresponding to entry c of pi based upon mastery and nonmastery of the K skills.

Author(s)

James Joseph Balamuta and Steven Andrew Culpepper

See Also

[simcdm::attribute_classes\(\)](#) and [simcdm::attribute_inv_bijection\(\)](#)

Examples

```
# Define number of subjects and attributes
N = 100
K = 3

# Generate a sample from the Latent Attribute Profile (Alpha) Matrix
# By default, we sample from a uniform distribution weighting of classes.
alphas_builtin = sim_subject_attributes(N, K)

# Generate a sample using custom probabilities from the
# Latent Attribute Profile (Alpha) Matrix
probs = rep(1 / (2 ^ K), 2 ^ K)
alphas_custom = sim_subject_attributes(N, K, probs)
```

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