Package 'MAT'

July 21, 2025

Type Package

Title Multidimensional Adaptive Testing

Version 2.3.2

Date 2024-06-1

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Description Simulates Multidimensional Adaptive Testing using the multidimensional three-parameter logistic model as described in Segall (1996) <doi:10.1007/BF02294343>, van der Linden (1999) <doi:10.3102/10769986024004398>, Reckase (2009) <doi:10.1007/978-0-387-89976-3>, and Mulder & van der Linden (2009) <doi:10.1007/s11336-008-9097-5>.

License GPL (>= 2.10)

Imports Rcpp (>= 1.0.0), methods

LinkingTo Rcpp, RcppArmadillo

LazyLoad yes

NeedsCompilation yes

Repository CRAN

Date/Publication 2024-06-01 18:22:46 UTC

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MAT-package *Multidimensional Adaptive Testing (MAT)*

Description

MAT is a package to simulate Multidimensional Adaptive Testing (MAT) for the Multidimensional 3-Parameter Logistic (M3PL) Model as described in Segall (1996), Reckase (2009), and Mulder & van der Linden (2009).

Author(s)

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References

1. Choi, S. W., & King, D. R. (2015). R Package MAT: Simulation of multidimensional adaptive testing for dichotomous IRT models. Applied Psychological Measurement, 39(3), 239-240.
2. Segall, D. O. (1996). Multidimensional adaptive testing, Psychometrika, 61(2), 331-354
3. van der Linden, W. J. (1999). Multidimensional adaptive testing with a minimum error-variance criterion, Journal of Educational and Behavioral Statistics, 24(4), 398-412.
4. Mulder, J., & van der Linden, W. J. (2009). Multidimensional adaptive testing with optimal design criteria for item selection, Psychometrika, 74(2), 273-296.
5. Reckase, M. D. (2009). Multidimensional Item Response Theory. New York: Springer.

Examples

```
#load sample item parameters containing 180 items measuring three dimensions
data(sample.ipar)
#create a variance-covariance (correlation) matrix
vcv1<-diag(3); vcv1[lower.tri(vcv1,diag=FALSE)]<-c(.5,.6,.7)
#simulate item responses
resp1<-simM3PL(sample.ipar, vcv1, 3, n.simulee = 100)$resp
#specify target content distributions
target.content.dist1<-c(1/3,1/3,1/3)
#content category designations for items
content.cat1<-rep(1:3,rep(60,3))
#simulate multidimensional adaptive testing
MCAT.1<-MAT(sample.ipar,
            resp1,
            vcv1,
            target.content.dist=target.content.dist1,
            content.cat=content.cat1,
            ncc=3,
            p=3,
            selectionMethod="A",
            topN=1,
```

```
selectionType="FISHER",
stoppingCriterion="CONJUNCTIVE",
minNI=10,
maxNI=30)
```

MAT *Multidimensional Adaptive Testing (MAT)*

Description

MAT is a package to simulate multidimensional adaptive testing for the Multidimensional 3-Parameter Logistic (M3PL) model.

Usage

```
MAT(ipar, resp, cors,
    target.content.dist = NULL, content.cat = NULL, ncc = 1,
    content.order = NULL, p = stop("p is required"),
    selectionMethod = c("D", "A", "C", "R"),
    selectionType = c("FISHER", "BAYESIAN"), c.weights = NA,
    stoppingCriterion = c("CONJUNCTIVE", "COMPENSATORY"),
    topN = 1, minNI = 10, maxNI = 30, minSE = 0.3, D = 1,
    maxIter = 30, conv = 0.001, minTheta = -4, maxTheta = 4,
    plot.audit.trail = TRUE, theta.labels = NULL, easiness = TRUE)
```

Arguments

ipar	a data frame containing M3PL item parameters, specifically a1, a2, ... , d, and c
resp	a data frame (that will be converted to a numeric matrix) of item responses, e.g., R1, R2, ..., R180
cors	a square matrix of the lower diagonal elements of a variance-covariance (VCV) matrix, including 1's in the main diagonal
target.content.dist	an optional vector of target content distributions summed to 1.0, e.g., c(0.25,0.5,0.25)
content.cat	an optional vector specifying content designations
ncc	the number of content categories (default=1, i.e., no content balancing)
content.order	an optional vector specifying administration order of content categories, e.g., c(3,1,2)
p	the number of latent dimensions
selectionMethod	item selection criterion: "D"=D-optimality, "A"=A-optimality, "C"=C-optimality, "R"=Random (default="D")
selectionType	item selection method type: "FISHER"=Fisher information, "BAYESIAN"=adds inverse prior VCV

c.weights	an optional vector of weights of length p when selectionMethod="C"
stoppingCriterion	stopping criterion: "CONJUNCTIVE"=SEs for all dimensions must be met, "COMPENSATORY"=the generalized variance or SEs weighted by c-weights must be met
topN	Randomesque exposure control: selects an item randomly from the top N most informative items (default=1, no exposure control)
minNI	minimum number of items to administer (default=10)
maxNI	maximum number of items to administer (default=30)
minSE	minimum SE for stopping (default=0.3)
D	scaling constant: 1.7 or 1.0 (default=1.0)
maxIter	maximum number of Fisher scoring (default=30)
conv	convergence criterion for Fisher scoring (default=0.001)
minTheta	minimum theta value for plotting (default=-4)
maxTheta	maximum theta value for plotting (default=4)
plot.audit.trail	show CAT audit trail: T or F (default=T)
theta.labels	theta labels for plotting (default=c("Theta 1","Theta 2",...))
easiness	logical, T if d is related to the *easiness* of items per Reckase, F otherwise

Details

The purpose of this function is to simulate multidimensional adaptive testing based on the Multidimensional 3-Parameter Logistic (M3PL) model (Reckase, 2009):

$$P_i(\theta) \equiv P(U_i = 1|\boldsymbol{\theta}, \mathbf{a}_i, d_i, c_i) \equiv c_i + \frac{1 - c_i}{1 + exp[-D(\mathbf{a}_i \cdot \boldsymbol{\theta} + d_i)]}$$

where $\mathbf{a}_i$ is a vector of discrimination parameters of item *i*, $\boldsymbol{\theta}$ is a vector of abilities, c_i is a scalar representing the guessing parameter of item *i*, d_i is a scalar representing the easiness of item *i*. Thetas are estimated using the Bayesian maximum a posteriori (MAP) estimator and the Fisher scoring method. Three item selection criteria are available: D-optimality, A-optimality, and C-optimality (Segall, 1996; van der Linden, 1999; Mulder & van der Linden, 2009). An option is provided to add the inverse of a prior variance-covariance matrix to the multivariate information matrix (selectionType="BAYESIAN"). The stopping condition can be specified as a conjunctive criterion or a compensatory criterion. Content balancing can be imposed by specifying target content distributions. An exposure control option is provided via the randomesque technique.

Value

Returns a list of class "MAT" with the following components:

call	function call stack
items.used	a matrix of items administered
selected.item.resp	a matrix containing item responses for selected items

ni.administered	a vector of the number of items administered
theta.CAT	a matrix of theta estimates from CAT
se.CAT	a matrix of SE estimates from CAT
theta.history	a matrix of theta history from CAT
se.history	a matrix of SE history from CAT
theta.Full	a matrix of theta estimates based on the full bank
se.Full	a matrix of SE estimates based on the full bank
ipar	a matrix of item parameters
p	the number of latent dimensions

Note

1. The MAT function performs a number of checks to determine if the arguments for content balancing and content ordering have been specified correctly. If the arguments have not been specified correctly, content balancing and/or content ordering will not be used for the simulation. Additionally, a warning message will be printed to the console detailing the misspecification.
2. Content ordering is only available for fixed-length CAT. Namely, to invoke a particular content order, the user must set the minimum number of items equal to the maximum number of items (e.g., minNI=30 & maxNI=30).

Note

requires **MASS**

Author(s)

Seung W. Choi and David R. King

References

1. Segall, D. O. (1996). Multidimensional adaptive testing, Psychometrika, 61(2), 331-354
2. van der Linden, W. J. (1999). Multidimensional adaptive testing with a minimum error-variance criterion, Journal of Educational and Behavioral Statistics, 24(4), 398-412.
3. Mulder, J., & van der Linden, W. J. (2009). Multidimensional adaptive testing with optimal design criteria for item selection, Psychometrika, 74(2), 273-296.
4. Reckase, M. D. (2009). Multidimensional Item Response Theory. New York: Springer.

Examples

```
## Not run: MCAT.1<-MAT(ipar1,
            resp1,
            vcv1,
            target.content.dist=target.content.dist1,
            content.cat=content.cat1,
            ncc=3,
```

```
                p=3,
                selectionMethod="A",
                topN=1,
                selectionType="FISHER",
                stoppingCriterion="CONJUNCTIVE",
                minNI=10,
                maxNI=30)

## End(Not run)
```

`sample.ipar` *Sample item parameters*

Description

A sample item parameter file containing 180 Multidimensional 3-PL (M3PL) model.

Usage

```
data(sample.ipar)
```

Format

A data frame with item parameters for 180 items.

`a1` the discrimination parameter for theta 1

`a2` the discrimination parameter for theta 2

`a3` the discrimination parameter for theta 3

`d` the easiness parameter, d=-a*b

`c` the guessing parameter

Details

First 60 items are primarily loaded on theta 1, second 60 on theta 2, and last 60 on theta 3.

Examples

```
data(sample.ipar)
```

simM3PL *Simulate M3PL item responses*

Description

Simulates item responses according to the Multidimensional 3-Parameter Logistic (M3PL) model

Usage

```
simM3PL(ipar, cors, p, n.simulee = 100, D = 1, easiness = T, seed = NULL)
```

Arguments

ipar	a data frame containing M3PL item parameters, specifically a1, a2, ... , d, and c
cors	a square matrix of the lower diagonal elements of a variance-covariance (VCV) matrix, including 1's in the main diagonal
p	the number of latent dimensions
n.simulee	the number of simulees to generate
D	scaling constant: 1.7 or 1.0 (default=1.0)
easiness	logical, T if d is related to the *easiness* of items per Reckase, F otherwise
seed	random number seed

Details

This function simulates item responses according to the Multidimensional 3-Parameter Logistic (M3PL) model using the item parameters input to the function. Thetas are drawn from the multivariate standard normal distribution with the population variance-covariance (correlation) matrix input to the function.

Value

call	function call stack
theta	a *n.simulee* by *p* matrix of true theta values
resp	a data frame of simulated item responses named "R1", "R2", ...

Author(s)

Seung W. Choi

References

Reckase, M. D. (2009). Multidimensional Item Response Theory. New York: Springer.

Examples

```
data(sample.ipar)
vcv1<-diag(3)
vcv1[lower.tri(vcv1,diag=FALSE)]<-c(.5,.6,.7)
resp1<-simM3PL(sample.ipar, vcv1, 3, n.simulee = 100, seed = 1234)$resp
```

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