# Package 'MAT'

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**Type** Package

**Title** Multidimensional Adaptive Testing

**Version** 2.2

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**Description** Simulate Multidimensional Adaptive Testing

**License** GPL (>= 2)

**Imports** Rcpp (>= 0.11.2)

**LinkingTo** Rcpp, RcppArmadillo

**LazyLoad** yes

**NeedsCompilation** yes

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## R topics documented:

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.

## Details

| | |
|---|---|
| Package: | MAT |
| Type: | Package |
| Version: | 2.0 |
| Date: | 2011-01-25 |
| License: | GPL |
| LazyLoad: | yes |

## Author(s)

Seung W. Choi and David R. King

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## 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

```
#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)
```

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MAT *Multidimensional Adaptive Testing (MAT)*

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## 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 = T, theta.labels = NULL, easiness=T)
```

## 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)
```

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`sample.ipar` *Sample item parameters*

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## 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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