Package ‘MultiLCIRT’

May 7, 2026

Type Package

Title Multidimensional Latent Class Item Response Theory Models

Version 2.12

Date 2025-06-28

Author Francesco Bartolucci [aut, cre],
Silvia Bacci [aut],
Michela Gnaldi [aut]

Maintainer Francesco Bartolucci <francesco.bartolucci@unipg.it>

Description Framework for the Item Response Theory analysis of dichotomous and ordinal polytomous outcomes under the assumption of multidimensionality and discreteness of the latent traits. The fitting algorithms allow for missing responses and for different item parameterizations and are based on the Expectation-Maximization paradigm. Individual covariates affecting the class weights may be included in the new version (since 2.1).

License GPL (>= 2)

Depends R (>= 2.0.0), MASS, limSolve

NeedsCompilation yes

Repository CRAN

Date/Publication 2025-06-28 06:30:02 UTC

Contents

`MultiLCIRT-package` *Multidimensional Latent Class (LC) Item Response Theory (IRT) Models*

Description

This package provides a flexible framework for the Item Response Theory (IRT) analysis of dichotomous and ordinal polytomous outcomes under the assumption of multidimensionality and discreteness of latent traits (abilities). Every level of the abilities identify a latent class of subjects. The fitting algorithms are based on the Expectation-Maximization (EM) paradigm and allow for missing responses and for different item parameterizations. The package also allows for the inclusion individual covariates affecting the class weights.

Details

Package:	MultiLCIRT
Type:	Package
Version:	2.11
Date:	2017-05-19
License:	GPL (>= 2)

Function `est_multi_poly` performs the parameter estimation of the following IRT models, allowing for one or more latent traits:

- Binary responses: Rasch model, 2-Parameter Logistic (2PL) model;

- Ordinal polythomous responses: Samejima's Graded Response Model (GRM) and constrained versions with fixed discrimination parameters and/or additive decomposition of difficulty parameters (rating scale parameterization); Muraki's Generalized Partial Credit Model and constrained versions with fixed discrimination parameters and/or additive decomposition of difficulty parameters, such as Partial Credit Model and Rating Scale Model.

The basic input arguments for est_multi_poly are the person-item matrix of available response configurations and the corresponding frequencies, the number of latent classes, the type of link function, the specification of constraints on the discriminating and difficulty item parameters, and the allocation of items to the latent traits. Missing responses are coded with NA, and units and items without responses are automatically removed.

Function `test_dim` performs a likelihood ratio test to choose the optimal number of latent traits (or dimensions) by comparing nested models that differ in the number of latent traits, being all the other elements let equal (i.e., number of latent classes, type of link function, constraints on item parameters). The basic input arguments for `test_dim` are similar as those for `est_multi_poly`.

Function `class_item` performs a hierarchical clustering of items based on a specified LC IRT model. The basic input arguments are given by the number of latent classes, the type of model, and the constraints on the item parameters (only for polythomous responses). An allocation of items to the different latent traits is obtained depending on the cut-point of the resulting dendrogram.

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

Maintainer: Francesco Bartolucci <bart@stat.unipg.it>

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2014), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Communication in Statistics - Theory and Methods*, **43**, 787-800.

Bartolucci, F., Bacci, S. and Gnaldi, M. (2014), MultiLCIRT: An R package for multidimensional latent class item response models, *Computational Statistics and Data Analysis*, **71**, 971-985.

Examples

```
## Estimation of different Multidimensional LC IRT models with binary
## responses
# Aggregate data
data(naep)
X = as.matrix(naep)
out = aggr_data(X)
S = out$data_dis
yv = out$freq
# Define matrix to allocate each item on one dimension
multi1 = rbind(c(1,2,9,10),c(3,5,8,11),c(4,6,7,12))
# Three-dimensional LC Rasch model with 4 latent classes
# less severe tolerance level to check convergence (to be modified)
out1 = est_multi_poly(S,yv,k=4,start=0,link=1,multi=multi1,tol=10^-6)
```

aggr_data *Aggregate data*

Description

Given a matrix of configurations (covariates and responses) unit-by-unit, this function finds the corresponding matrix of distinct configurations and the corresponding vector of frequencies (it does not work properly with missing data).

Usage

```
aggr_data(data, disp=FALSE, fort=FALSE)
```

Arguments

data	matrix of covariate and unit-by-unit response configurations
disp	to display partial results
fort	to use fortran routines when possible

Value

data_dis	matrix of distinct configurations
freq	vector of corresponding frequencies
label	the index of each provided response configuration among the distinct ones

Author(s)

Francesco Bartolucci - University of Perugia (IT)

Examples

```
# draw a matrix of random responses and find distinct responses
X = matrix(sample(5,100,replace=TRUE),50,2)
out = aggr_data(X)

# find the distinct responses and the corresponding vector of frequencies
# for naep data
data(naep)
X = as.matrix(naep)
out = aggr_data(X)
length(out$freq)
```

class_item — *Hierarchical classification of test items*

Description

It performs a hierarchical classification of a set of test items on the basis of the responses provided by a sample of subjects. The classification is based on a sequence of likelihood ratio tests between pairs of multidimensional models suitably formulated.

Usage

```
class_item(S, yv, k, link = 1, disc = 0, difl = 0, fort = FALSE,
           disp = FALSE, tol = 10^-10)
```

Arguments

`S`	matrix of all response sequences observed at least once in the sample and listed row-by-row (use 999 for missing response)
`yv`	vector of the frequencies of every response configuration in `S`
`k`	number of ability levels (or latent classes)
`link`	type of link function (1 = global logits, 2 = local logits); with global logits the Graded Response model results; with local logits the Partial Credit results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
`disc`	indicator of constraints on the discriminating indices (0 = all equal to one, 1 = free)
`difl`	indicator of constraints on the difficulty levels (0 = free, 1 = rating scale parametrization)
`fort`	to use fortran routines when possible
`disp`	to display the likelihood evolution step by step
`tol`	tolerance level for convergence

Value

`merge`	input for the dendrogram represented by the `R` function `plot`
`height`	input for the dendrogram represented by the `R` function `plot`
`lk`	maximum log-likelihood of the model resulting from each aggregation
`np`	number of free parameters of the model resulting from each aggregation
`lk0`	maximum log-likelihood of the latent class model
`np0`	number of free parameters of the latent class model
`groups`	list of groups resulting (step-by-step) from the hierarchical clustering
`dend`	hclust object to represent the histogram
`call`	command used to call the function

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2012), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Technical report*, http://arxiv.org/abs/1201.4667.

Examples

```
## Not run:
## Model-based hierarchical classification of items from simulated data
# Setup
r = 6  # number of items
n = 1000  # sample size
bev = rep(0,r)
k = r/2
multi = rbind(1:(r/2),(r/2+1):r)
L = chol(matrix(c(1,0.6,0.6,1),2,2))
data = matrix(0,n,r)
model = 1
# Create data
Th = matrix(rnorm(2*n),n,2)
for(i in 1:n) for(j in 1:r){
if(j<=r/2){
     pc = exp(Th[i,1]-bev[j]); pc = pc/(1+pc)
}else{
pc = exp(Th[i,2]-bev[j]); pc = pc/(1+pc)
    }
    data[i,j] = runif(1)<pc
}
# Aggregate data
out = aggr_data(data)
S = out$data_dis
yv = out$freq
# Create dendrogram for items classification, by assuming k=3 latent
# classes and a Rasch parameterization
out = class_item(S,yv,k=3,link=1)
summary(out)
plot(out$dend)

## End(Not run)

## Not run:
## Model-based hierarchical classification of NAEP items
# Aggregate data
data(naep)
X = as.matrix(naep)
out = aggr_data(X)
```

```
S = out$data_dis
yv = out$freq
# Create dendrogram for items classification, by assuming k=4 latent
# classes and a Rasch parameterization
out = class_item(S,yv,k=4,link=1)
summary(out)
plot(out$dend)

## End(Not run)
```

---

compare_models *Compare different models fitted by est_multi_poly*

Description

Given different outputs provided by est_multi_poly, the function compare the different models providing a unified table.

Usage

```
compare_models(out1, out2, out3=NULL, out4=NULL, out5=NULL,
                 nested=FALSE)
```

Arguments

out1	output from the 1st fitting
out2	output from the 2nd fitting
out3	output from the 3rd fitting
out4	output from the 4th fitting
out5	output from the 5th fitting
nested	to compare each model with the first in terms of LR test

Value

table	table summarizing the comparison between the models

Author(s)

Francesco Bartolucci - University of Perugia (IT)

est_multi_glob *Fit marginal regression models for categorical responses*

Description

It estimates marginal regression models to datasets consisting of a categorical response and one or more covariates by a Fisher-scoring algorithm; this is an internal function.

Usage

```
est_multi_glob(Y, X, model, ind = 1:nrow(Y), be = NULL, Dis = NULL,
               dis = NULL, disp=FALSE, only_sc = FALSE, Int = NULL,
               der_single = FALSE)
```

Arguments

Y	matrix of response configurations
X	array of all distinct covariate configurations
model	type of logit (g = global, l = local, m = multinomial)
ind	vector to link responses to covariates
be	initial vector of regression coefficients
Dis	matrix for inequality constraints on be
dis	vector for inequality constraints on be
disp	to display partial output
only_sc	to exit giving only the score
Int	matrix of the fixed intercepts
der_single	to require single derivatives

Value

be	estimated vector of regression coefficients
lk	log-likelihood at convergence
Pdis	matrix of the probabilities for each distinct covariate configuration
P	matrix of the probabilities for each covariate configuration
sc	score
Sc	single derivative (if der_single=TRUE)

Author(s)

Francesco Bartolucci - University of Perugia (IT)

References

Colombi, R. and Forcina, A. (2001), Marginal regression models for the analysis of positive association of ordinal response variables, *Biometrika*, **88**, 1007-1019.

Glonek, G. F. V. and McCullagh, P. (1995), Multivariate logistic models, *Journal of the Royal Statistical Society, Series B*, **57**, 533-546.

`est_multi_poly` *Estimate multidimensional LC IRT model for dichotomous and polytomous responses*

Description

The function performs maximum likelihood estimation of the parameters of the IRT models assuming a discrete distribution for the ability. Every ability level corresponds to a latent class of subjects in the reference population. Maximum likelihood estimation is based on Expectation- Maximization algorithm.

Usage

```
est_multi_poly(S, yv = rep(1,ns), k, X = NULL, start = 0, link = 0,
               disc = 0, difl = 0, multi = NULL, piv = NULL,
               Phi = NULL, gac = NULL, De = NULL, fort = FALSE,
               tol = 10^-10, disp = FALSE, output = FALSE,
               out_se = FALSE, glob = FALSE)
```

Arguments

`S`	matrix of all response sequences observed at least once in the sample and listed row-by-row (use NA for missing response)
`yv`	vector of the frequencies of every response configuration in `S`
`k`	number of ability levels (or latent classes)
`X`	matrix of covariates that affects the weights
`start`	method of initialization of the algorithm (0 = deterministic, 1 = random, 2 = arguments given as input)
`link`	type of link function (0 = no link function, 1 = global logits, 2 = local logits); with no link function the Latent Class model results; with global logits the Graded Response model results; with local logits the Partial Credit results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
`disc`	indicator of constraints on the discriminating indices (0 = all equal to one, 1 = free)
`difl`	indicator of constraints on the difficulty levels (0 = free, 1 = rating scale parameterization)

multi	matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row
piv	initial value of the vector of weights of the latent classes (if start=2)
Phi	initial value of the matrix of the conditional response probabilities (if start=2)
gac	initial value of the complete vector of discriminating indices (if start=2)
De	initial value of regression coefficients for the covariates (if start=2)
fort	to use fortran routines when possible
tol	tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
disp	to display the likelihood evolution step by step
output	to return additional outputs (Phi,Pp,Piv)
out_se	to return standard errors
glob	to use global logits in the covariates

Value

piv	estimated vector of weights of the latent classes (average of the weights in case of model with covariates)
Th	estimated matrix of ability levels for each dimension and latent class
Bec	estimated vector of difficulty levels for every item (split in two vectors if difl=1)
gac	estimated vector of discriminating indices for every item (with all elements equal to 1 with Rasch parametrization)
fv	vector indicating the reference item chosen for each latent dimension
Phi	array of the conditional response probabilities for every item and latent class
De	matrix of regression coefficients for the multinomial logit model on the class weights
Piv	matrix of the weights for every response configuration (if output=TRUE)
Pp	matrix of the posterior probabilities for each response configuration and latent class (if output=TRUE)
lk	log-likelihood at convergence of the EM algorithm
np	number of free parameters
aic	Akaike Information Criterion index
bic	Bayesian Information Criterion index
ent	Etropy index to measure the separation of classes
lkv	Vector to trace the log-likelihood evolution across iterations (if output=TRUE)
seDe	Standard errors for De (if output=TRUE)
separ	Standard errors for vector of parameters containing Th and Be (if out_se=TRUE)
sega	Standard errors for vector of discrimination indices (if out_se=TRUE)
Vn	Estimated variance-covariance matrix for all parameter estimates (if output=TRUE)

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2014), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Communication in Statistics - Theory and Methods*, **43**, 787-800.

Examples

```
## Estimation of different Multidimensional LC IRT models with binary
# responses
# Aggregate data
data(naep)
X = as.matrix(naep)
out = aggr_data(X)
S = out$data_dis
yv = out$freq
# Define matrix to allocate each item to one dimension
multi1 = rbind(c(1,2,9,10),c(3,5,8,11),c(4,6,7,12))
# Three-dimensional Rasch model with 3 latent classes
# the tolerance level has been rise to increase the speed (to be reported
# to a smaller value)
out1 = est_multi_poly(S,yv,k=3,start=0,link=1,multi=multi1,tol=10^-6)
## Not run:
# Three-dimensional 2PL model with 3 latent classes
out2 = est_multi_poly(S,yv,k=3,start=0,link=1,disc=1,multi=multi1)

## End(Not run)

## Not run:
## Estimation of different Multidimensional LC IRT models with ordinal
# responses
# Aggregate data
data(hads)
X = as.matrix(hads)
out = aggr_data(X)
S = out$data_dis
yv = out$freq
# Define matrix to allocate each item to one dimension
multi1 = rbind(c(2,6,7,8,10,11,12),c(1,3,4,5,9,13,14))
# Bidimensional LC Graded Response Model with 3 latent classes
# (free discriminating and free difficulty parameters)
out1 = est_multi_poly(S,yv,k=3,start=0,link=1,disc=1,multi=multi1)
# Bidimensional LC Partial Credit Model with 3 latent classes
# (constrained discrimination and free difficulty parameters)
out2 = est_multi_poly(S,yv,k=3,start=0,link=2,multi=multi1)
# Bidimensional LC Rating Scale Model with 3 latent classes
```

```
# (constrained discrimination and constrained difficulty parameters)
out3 = est_multi_poly(S,yv,k=3,start=0,link=2,difl=1,multi=multi1)

## End(Not run)

## Not run:
## Estimation of LC model with covariates
# gerate covariates
be = c(0,1,-1)
X = matrix(rnorm(2000),1000,2)
u = cbind(1,X)
p = exp(u)/(1+exp(u))
c = 1+(runif(1000)<p)
Y = matrix(0,1000,5)
la = c(0.3,0.7)
for(i in 1:1000) Y[i,] = runif(5)<la[c[i]]
# fit the model with k=2 and k=3 classes
out1 = est_multi_poly(Y,k=2,X=X)
out2 = est_multi_poly(Y,k=3,X=X)
# fit model with k=2 and k=3 classes in fortran
out3 = est_multi_poly(Y,k=2,X=X,fort=TRUE)
out4 = est_multi_poly(Y,k=3,X=X,fort=TRUE)

## End(Not run)
```

`est_multi_poly_clust` *Estimate multidimensional and multilevel LC IRT model for dichotomous and polytomous responses*

Description

The function performs maximum likelihood estimation of the parameters of the IRT models assuming a discrete distribution for the ability and a discrete distribution for the latent variable at cluster level. Every ability level corresponds to a latent class of subjects in the reference population. Maximum likelihood estimation is based on Expectation- Maximization algorithm.

Usage

```
est_multi_poly_clust(S, kU, kV, W = NULL, X = NULL, clust,
                     start = 0, link = 0,  disc = 0, difl = 0,
                     multi = 1:J, piv = NULL, Phi = NULL,
                     gac = NULL, DeU = NULL, DeV = NULL,
                     fort = FALSE, tol = 10^-10, disp = FALSE,
                     output = FALSE)
```

Arguments

S	matrix of all response sequences observed at least once in the sample and listed row-by-row (use NA for missing response)

kU	number of support points (or latent classes at cluster level)
kV	number of ability levels (or latent classes at individual level)
W	matrix of covariates that affects the weights at cluster level
X	matrix of covariates that affects the weights at individual level
clust	vector of cluster indicator for each unit
start	method of initialization of the algorithm (0 = deterministic, 1 = random, 2 = arguments given as input)
link	type of link function (0 = no link function, 1 = global logits, 2 = local logits); with no link function the Latent Class model results; with global logits the Graded Response model results; with local logits the Partial Credit results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
disc	indicator of constraints on the discriminating indices (0 = all equal to one, 1 = free)
difl	indicator of constraints on the difficulty levels (0 = free, 1 = rating scale parameterization)
multi	matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row
piv	initial value of the vector of weights of the latent classes (if start=2)
Phi	initial value of the matrix of the conditional response probabilities (if start=2)
gac	initial value of the complete vector of discriminating indices (if start=2)
DeU	initial value of regression coefficients for the covariates in W (if start=2)
DeV	initial value of regression coefficients for the covariates in X (if start=2)
fort	to use fortran routines when possible
tol	tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
disp	to display the likelihood evolution step by step
output	to return additional outputs (Phi,Pp,Piv)

Value

piv	estimated vector of weights of the latent classes (average of the weights in case of model with covariates)
Th	estimated matrix of ability levels for each dimension and latent class
Bec	estimated vector of difficulty levels for every item (split in two vectors if difl=1)
gac	estimated vector of discriminating indices for every item (with all elements equal to 1 with Rasch parametrization)
fv	vector indicating the reference item chosen for each latent dimension
Phi	array of the conditional response probabilities for every item and latent class
De	matrix of regression coefficients for the multinomial logit model on the class weights

Piv	matrix of the weights for every response configuration (if output=TRUE)
Pp	matrix of the posterior probabilities for each response configuration and latent class (if output=TRUE)
lk	log-likelhood at convergence of the EM algorithm
np	number of free parameters
aic	Akaike Information Criterion index
bic	Bayesian Information Criterion index
ent	Etropy index to measure the separation of classes
lkv	Vector to trace the log-likelihood evolution across iterations (if output=TRUE)
seDe	Standard errors for De (if output=TRUE)
separ	Standard errors for vector of parameters containing Th and Be (if output=TRUE)
sega	Standard errors for vector of discrimination indices (if output=TRUE)
Vn	Estimated variance-covariance matrix for all parameter estimates (if output=TRUE)

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2014), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Communication in Statistics - Theory and Methods*, **43**, 787-800.

Examples

```
## Not run:
# generate covariate at cluster level
nclust = 200
W = matrix(round(rnorm(nclust)*2,0)/2,nclust,1)
la = exp(W)/(1+exp(W))
U = 1+1*(runif(nclust)<la)
clust = NULL
for(h in 1:nclust){
nh = round(runif(1,5,20))
clust = c(clust,h*rep(1,nh))
}
n = length(clust)

# generate covariates
DeV = rbind(c(1.75,1.5),c(-0.25,-1.5),c(-0.5,-1),c(0.5,1))
X = matrix(round(rnorm(2*n)*2,0)/2,n,2)
Piv = cbind(0,cbind(U[clust]==1,U[clust]==2,X)%*%DeV)
Piv = exp(Piv)*(1/rowSums(exp(Piv)))
V = rep(0,n)
```

```
for(i in 1:n) V[i] = which(rmultinom(1,1,Piv[i,])==1)

# generate responses
la = c(0.2,0.5,0.8)
Y = matrix(0,n,10)
for(i in 1:n) Y[i,] = runif(10)<la[V[i]]

# fit the model with k1=3 and k2=2 classes
out1 = est_multi_poly_clust(Y,kU=2,kV=3,W=W,X=X,clust=clust)
out2 = est_multi_poly_clust(Y,kU=2,kV=3,W=W,X=X,clust=clust,disp=TRUE,
                            output=TRUE)
out3 = est_multi_poly_clust(Y,kU=2,kV=3,W=W,X=X,clust=clust,disp=TRUE,
                            output=TRUE,start=2,Phi=out2$Phi,gac=out2$gac,
                            DeU=out2$DeU,DeV=out2$DeV)
# Rasch
out4 = est_multi_poly_clust(Y,kU=2,kV=3,W=W,X=X,clust=clust,link=1,
                            disp=TRUE,output=TRUE)
out5 = est_multi_poly_clust(Y,kU=2,kV=3,W=W,X=X,clust=clust,link=1,
                            disc=1,disp=TRUE,output=TRUE)

## End(Not run)
```

---

hads	*Dataset about measurement of anxiety and depression in oncological patients*

Description

This data set contains the responses of 201 oncological patients to 14 ordinal polytomous items that measure anxiety (7 items) and depression (7 items), according to the Hospital Anxiety and Depression Scale questionnaire.

Usage

```
data(hads)
```

Format

A data frame with 201 observations on 14 items:

`item1` measure of depression

`item2` measure of anxiety

`item3` measure of depression

`item4` measure of depression

`item5` measure of depression

`item6` measure of anxiety

`item7` measure of anxiety

`item8` measure of anxiety

`item9` measure of depression

`item10` measure of anxiety

`item11` measure of anxiety

`item12` measure of anxiety

`item13` measure of depression

`item14` measure of depression

Details

All items have 4 response categories: the minimum value 0 corresponds to a low level of anxiety or depression, whereas the maximum value 3 corresponds to a high level of anxiety or depression.

References

Zigmond, A. and Snaith, R. (1983), The hospital anxiety and depression scale, *Acta Psychiatrika Scandinavica*, **67**, 361-370.

Examples

```
data(hads)
## maybe str(hads)
str(hads)
```

`inv_glob` *Invert marginal logits*

Description

Function used within `est_multi_glob` to invert marginal logits and fit the marginal regression model; this is an internal function.

Usage

```
inv_glob(eta, type = "g", der = F)
```

Arguments

`eta`	vector of logits
`type`	type of logit (l = local-logits, g = global-logits)
`der`	indicator that the derivative of the canonical parameters with respect to the vector of marginal logits is required (F = not required, T = required)

Value

p	vector of probabilities
D	derivative of the canonical parameters with respect to the vector of marginal logits (if der = T)

Author(s)

Francesco Bartolucci - University of Perugia (IT)

References

Colombi, R. and Forcina, A. (2001), Marginal regression models for the analysis of positive association of ordinal response variables, *Biometrika*, **88**, 1007-1019.

Glonek, G. F. V. and McCullagh, P. (1995), Multivariate logistic models, *Journal of the Royal Statistical Society, Series B*, **57**, 533-546.

`lk_obs_score` *Compute observed log-likelihood and score*

Description

Function used within `est_multi_poly` to compute observed log-likelihood and score.

Usage

```
lk_obs_score(par_comp, lde, lpar, lga, S, R, yv, k, rm, l, J, fv, link,
         disc, indga, glob, refitem, miss, ltype, XXdis, Xlabel,
         ZZ0, fort)
```

Arguments

par_comp	complete vector of parameters
lde	length of de
lpar	length of par
lga	length of ga
S	matrix of responses
R	matrix of observed responses indicator
yv	vector of frequencies
k	number of latent classes
rm	number of dimensions
l	number of respnse categories
J	number of items
fv	indicator of constrained parameters

link	link function
disc	presence of discrimination parameter
indga	indicator of gamma parameters
glob	indicator of gloabl parametrization for the covariates
refitem	vector of reference items
miss	indicator of presence of missing responses
ltype	type of logit
XXdis	array of covariates
Xlabel	indicator for covariate configuration
ZZ0	design matrix
fort	to use fortran

Value

lk	log-likelihood function
sc	score vector

Author(s)

Francesco Bartolucci - University of Perugia (IT)

---

lk_obs_score_clust *Compute observed log-likelihood and score*

Description

Function used within est_multi_poly to compute observed log-likelihood and score.

Usage

```
lk_obs_score_clust(par_comp, lde1, lde2, lpar, lga, S, R, kU, kV, rm,
                   l, J, fv, link, disc, indga, refitem, miss, ltype,
                   WWdis, Wlabel, XXdis, Xlabel, ZZ0, clust, fort)
```

Arguments

par_comp	complete vector of parameters
lde1	length of de
lde2	length of de
lpar	length of par
lga	length of ga
S	matrix of responses

R	matrix of observed responses indicator
kU	number of latent classes at cluster level
kV	number of latent classes at individual level
rm	number of dimensions
l	number of respnse categories
J	number of items
fv	indicator of constrained parameters
link	link function
disc	presence of discrimination parameter
indga	indicator of gamma parameters
refitem	vector of reference items
miss	indicator of presence of missing responses
ltype	type of logit
WWdis	array of covariates at cluster level
Wlabel	indicator for covariate configuration at cluster level
XXdis	array of covariates at individual level
Xlabel	indicator for covariate configuration at individual level
ZZ0	design matrix
clust	vector of cluster indicator for each unit
fort	to use fortran

Value

lk	log-likelihood function
sc	score vector

Author(s)

Francesco Bartolucci - University of Perugia (IT)

---

matr_glob *Matrices to compute generalized logits*

Description

It provides the matrices used to compute a vector of generalized logits on the basis of a vector of probabilities according to the formula *Co*log(Ma*p)*; this is an internal function.

Usage

```
matr_glob(l, type = "g")
```

Arguments

`l`	number of response categories
`type`	type of logit (l = local-logits, g = global-logits)

Value

`Co`	matrix of contrasts
`Ma`	marginalization matrix

Author(s)

Francesco Bartolucci - University of Perugia (IT)

References

Colombi, R. and Forcina, A. (2001), Marginal regression models for the analysis of positive association of ordinal response variables, *Biometrika*, **88**, 1007-1019.

Glonek, G. F. V. and McCullagh, P. (1995), Multivariate logistic models, *Journal of the Royal Statistical Society, Series B*, **57**, 533-546.

`naep` *NAEP dataset*

Description

This dataset contains the responses of a sample of 1510 examinees to 12 binary items on Mathematics. It has been extrapolated from a larger dataset collected in 1996 by the Educational Testing Service within the National Assessment of Educational Progress (NAEP) project.

Usage

```
data(naep)
```

Format

A data frame with 1510 observations on the following 12 items:

- `Item1` round to thousand place
- `Item2` write fraction that represents shaded region
- `Item3` multiply two negative integers
- `Item4` reason about sample space (number correct)
- `Item5` find amount of restaurant tip
- `Item6` identify representative sample
- `Item7` read dials on a meter
- `Item8` find (x, y) solution of linear equation

`Item9` translate words to symbols

`Item10` find number of diagonals in polygon from a vertex

`Item11` find perimeter (quadrilateral)

`Item12` reason about betweenness

References

Bartolucci, F. and Forcina, A. (2005), Likelihood inference on the underlying structure of IRT models. *Psychometrika*, **70**, 31-43.

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items. *Psychometrika*, **72**, 141-157.

Examples

```
data(naep)
## maybe str(naep)
str(naep)
```

`print.class_item` *Print the output of class_item object*

Description

Given the output from class_item, it is written in a readable form

Usage

```
## S3 method for class 'class_item'
print(x, ...)
```

Arguments

`x`	output from class_item
`...`	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

print.est_multi_poly — *Print the output of est_multi_poly object*

Description

Given the output from est_multi_poly, it is written in a readable form

Usage

```
## S3 method for class 'est_multi_poly'
print(x, ...)
```

Arguments

x	output from est_multi_poly
...	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

print.est_multi_poly_clust — *Print the output of est_multi_poly_clust object*

Description

Given the output from est_multi_poly_clust, it is written in a readable form

Usage

```
## S3 method for class 'est_multi_poly_clust'
print(x, ...)
```

Arguments

x	output from est_multi_poly_clust
...	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

`print.test_dim` *Print the output of test_dim object*

Description

Given the output from test_dim, it is written in a readable form

Usage

```
## S3 method for class 'test_dim'
print(x, ...)
```

Arguments

`x`	output from test_dim
`...`	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

`prob_multi_glob` *Global probabilities*

Description

It provides matrix of probabilities under different parametrizations.

Usage

```
prob_multi_glob(X, model, be, ind=(1:dim(X)[3]))
```

Arguments

`X`	array of all distinct covariate configurations
`model`	type of logit (g = global, l = local, m = multinomial)
`be`	initial vector of regression coefficients
`ind`	vector to link responses to covariates

Value

`Pdis`	matrix of distinct probability vectors
`P`	matrix of the probabilities for each covariate configuration

Author(s)

Francesco Bartolucci - University of Perugia (IT)

References

Colombi, R. and Forcina, A. (2001), Marginal regression models for the analysis of positive association of ordinal response variables, *Biometrika*, **88**, 1007-1019.

Glonek, G. F. V. and McCullagh, P. (1995), Multivariate logistic models, *Journal of the Royal Statistical Society, Series B*, **57**, 533-546.

`search.model` *Search for the global maximum of the log-likelihood*

Description

It search for the global maximum of the log-likelihood given a vector of possible number of classes to try for.

Usage

```
search.model(S, yv = rep(1,ns), kv, X = NULL, link = 0, disc = 0,
             difl = 0, multi = 1:J, fort = FALSE, tol = 10^-10,
             nrep = 2, glob = FALSE, disp=FALSE)
```

Arguments

`S`	matrix of all response sequences observed at least once in the sample and listed row-by-row (use 999 for missing response)
`yv`	vector of the frequencies of every response configuration in `S`
`kv`	vector of the possible numbers of latent classes
`X`	matrix of covariates that affects the weights
`link`	type of link function (1 = global logits, 2 = local logits); with global logits the Graded Response model results; with local logits the Partial Credit results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
`disc`	indicator of constraints on the discriminating indices (0 = all equal to one, 1 = free)
`difl`	indicator of constraints on the difficulty levels (0 = free, 1 = rating scale parametrization)
`multi`	matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row
`fort`	to use fortran routines when possible

`tol`	tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
`nrep`	number of repetitions of each random initialization
`glob`	to use global logits in the covariates
`disp`	to dispaly partial output

Value

`out.single`	output of each single model (as from est_multi_poly) for each k in kv
`bicv`	value of BIC index for each k in kv
`lkv`	value of log-likelihood for each k in kv

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2012), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Technical report*, http://arxiv.org/abs/1201.4667.

Examples

```
## Not run:
## Search Multidimensional LC IRT models for binary responses
# Aggregate data
data(naep)
X = as.matrix(naep)
out = aggr_data(X)
S = out$data_dis
yv = out$freq
# Define matrix to allocate each item on one dimension
multi1 = rbind(c(1,2,9,10),c(3,5,8,11),c(4,6,7,12))
out2 = search.model(S, yv = yv, kv=c(1:4),multi=multi1)

## End(Not run)
```

`standard.matrix` *Standardization of a matrix of support points on the basis of a vector of probabilities*

Description

Given a matrix of support points X and a corresponding vector of probabilities piv it computes the mean for each dimension, the variance covariance matrix, the correlation matrix, Spearman correlation matrix, and the standarized matrix Y

Usage

```
standard.matrix(X,piv)
```

Arguments

X	matrix of support points for the distribution included row by row
piv	vector of probabilities with the same number of elements as the rows of X

Value

mu	vector of the means
V	variance-covariance matrix
si2	vector of the variances
si	vector of standard deviations
Cor	Braives-Pearson correlation matrix
Sper	Spearman correlation matrix
Y	matrix of standardized support points

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

Examples

```
## Example of standardization of a randomly generated distribution
X = matrix(rnorm(100),20,5)
piv = runif(20); piv = piv/sum(piv)
out = standard.matrix(X,piv)
```

---

summary.class_item *Print the output of class_item object*

Description

Given the output from class_item, it is written in a readable form

Usage

```
## S3 method for class 'class_item'
summary(object, ...)
```

Arguments

object	output from class_item
...	further arguments passed to or from other methods

Value

`table`	summary of all the results

Author(s)

Francesco Bartolucci - University of Perugia (IT)

`summary.est_multi_poly` *Print the output of test_dim object*

Description

Given the output from est_multi_poly, it is written in a readable form

Usage

```
## S3 method for class 'est_multi_poly'
summary(object, ...)
```

Arguments

`object`	output from est_multi_poly
`...`	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

`summary.est_multi_poly_clust` *Print the output of est_multi_poly_clust object*

Description

Given the output from est_multi_poly_clust, it is written in a readable form

Usage

```
## S3 method for class 'est_multi_poly_clust'
summary(object, ...)
```

Arguments

`object`	output from est_multi_poly_clust
`...`	further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

`summary.test_dim` *Print the output of test_dim object*

Description

Given the output from test_dim, it is written in a readable form

Usage

```
## S3 method for class 'test_dim'
summary(object, ...)
```

Arguments

`object`	output from test_dim
`...`	further arguments passed to or from other methods

Value

`table`	summary of all the results

Author(s)

Francesco Bartolucci - University of Perugia (IT)

test_dim — *Likelihood ratio testing between nested multidimensional LC IRT models*

Description

The function tests a certain multidimensional model (restricted model) against a larger multidimensional model based on a higher number of dimensions. A typical example is testing a unidimensional model (and then the hypothesis of unidimensionality) against a bidimensional model. Both models are estimated by `est_multi_poly`.

Usage

```
test_dim(S, yv, k, link = 1, disc = 0, difl = 0, multi0 = 1:J,
         multi1, tol = 10^-10, disp = FALSE)
```

Arguments

`S`	matrix of all response sequences observed at least once in the sample and listed row-by-row (use 999 for missing response)
`yv`	vector of the frequencies of every response configuration in `S`
`k`	number of ability levels (or latent classes)
`link`	type of link function (1 = global logits, 2 = local logits); with global logits the Graded Response model results; with local logits the Partial Credit results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
`disc`	indicator of constraints on the discriminating indices (0 = all equal to one, 1 = free)
`difl`	indicator of constraints on the difficulty levels (0 = free, 1 = rating scale parametrization)
`multi0`	matrix specifying the multidimensional structure of the restricted model
`multi1`	matrix specifying the multidimensional structure of the larger model
`tol`	tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
`disp`	to display intermediate output

Value

`out0`	output for the restricted model obtained from `est_multi_poly`
`out1`	output for the larger model obtained from `est_multi_poly`
`dev`	likelihood ratio statistic
`df`	number of degrees of freedom of the test
`pv`	*p*-value for the test
`call`	command used to call the function

Author(s)

Francesco Bartolucci, Silvia Bacci, Michela Gnaldi - University of Perugia (IT)

References

Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, *Psychometrika*, **72**, 141-157.

Bacci, S., Bartolucci, F. and Gnaldi, M. (2012), A class of Multidimensional Latent Class IRT models for ordinal polytomous item responses, *Technical report*, http://arxiv.org/abs/1201.4667.

Examples

```
## Computation of the LR statistic testing unidimensionality on HADS data
# Aggregate data
data(hads)
X = as.matrix(hads)
out = aggr_data(X)
S = out$data_dis
yv = out$freq
# Define matrix to allocate each item on one dimension
multi1 = rbind(c(2,6,7,8,10,11,12),c(1,3,4,5,9,13,14))
# Compare unidimensional vs bidimensional Graded Response models with free
# discrimination and free difficulty parameters
# with less severe tollerance level (to be increased)
out = test_dim(S,yv,k=3,link=1,disc=1,multi1=multi1,tol=5*10^-4)
```

Index