

Package: irtbem2pl (via r-universe)

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Title Marginalized Bayesian Item Parameter Estimation, 2pl Model IRT

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Maintainer Juan Luis Legorreta Torres <jlegorreta2002@yahoo.com.mx>

Description Estimates item parameters of the two-parameter logistic (2PL) model in Item Response Theory (IRT) using the marginal Bayesian modal estimation via the Expectation-Maximization (EM) algorithm. The package calibrates item discrimination and difficulty parameters, yielding results comparable to software like 'BILOG-MG'.

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URL <https://github.com/juanluislegorretatorres/irtbem2pl>

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Author Juan Luis Legorreta Torres [aut, cre]

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Contents

dat01	2
irt2pl	2
irtbem2pl	4
irtchek2pl	6
LikelihoodInfo2pl	8
Prob.model	9

Index**10**

dat01*Dichotomous Response Dataset for IRT Calibration*

Description

A sample dataset containing binary examination responses used to demonstrate 2PL model parameter estimation.

Usage

```
data(dat01)
```

Format

A data frame with rows representing examinees and 20 columns representing items (ITEM001 to ITEM023). Responses are dichotomous where 1 indicates a correct response and 0 indicates an incorrect response.

irt2pl*Estimation of the 2PL Model via Marginal Bayesian Modal Estimation*

Description

Estimates item discrimination and difficulty parameters for the two-parameter logistic (2PL) model using an Expectation-Maximization (EM) algorithm with Bayesian priors.

Usage

```
irt2pl(  
  Model = Model,  
  data = data,  
  data.simple = data.simple,  
  CountNum = CountNum,  
  n.class = n.class,  
  Prior = Prior,  
  Par.est0 = Par.est0,  
  Par.SE0 = Par.SE0,  
  D = D,  
  np,  
  Tol = Tol,  
  max.ECycle = max.ECycle,  
  max.MCycle = max.MCycle,  
  n.Quadpts = n.Quadpts,  
  n.decimal = n.decimal,
```

```

    Theta.lim = Theta.lim,
    Missing = Missing,
    ParConstraint = ParConstraint,
    BiasSE = BiasSE,
    I = I,
    J = J,
    Time.Begin = Time.Begin
  )

```

Arguments

Model	An object specifying the IRT model configuration.
data	A data frame or matrix containing the raw response data.
data.simple	A simplified or matrix version of the response data.
CountNum	A numeric vector indicating the frequency of each response pattern.
n.class	An integer specifying the number of latent classes or groups.
Prior	A list containing the prior distributions for parameters A and B.
Par.est0	A list with the initial parameter estimates for the items.
Par.SE0	A list with the initial standard error estimates.
D	A numeric scaling constant (typically 1.7 or 1.0).
np	An integer representing the number of items or parameters.
Tol	A numeric value specifying the convergence tolerance limit.
max.ECycle	An integer indicating the maximum number of E-steps.
max.MCycle	An integer indicating the maximum number of M-steps.
n.Quadpts	An integer specifying the number of quadrature points.
n.decimal	An integer for decimal formatting in output objects.
Theta.lim	A numeric vector of length 2 defining the boundaries of theta.
Missing	A value or matrix specifying how missing data is handled.
ParConstraint	A logical value indicating if parameter constraints are applied.
BiasSE	A logical value specifying if bias-corrected standard errors are computed.
I	An integer representing the total number of examinees.
J	An integer representing the total number of items.
Time.Begin	A POSIXct timestamp marking the start of the execution.

Value

A list containing the calibrated item parameters, information matrices, and convergence metadata.

Description

' Estimates item parameters of the two-parameter logistic (2PL) model using marginal Bayesian modal estimation via the Expectation-Maximization (EM) algorithm. The results are similar to those of "BILOG-MG", from the book Item Response Theory Parameter Estimation Techniques.

Usage

```
irtbem2pl(
  data,
  PriorA = c(0, 0.25),
  PriorB = c(0, 4),
  InitialA = 1,
  InitialB = 0,
  Tol = 0.01,
  max.ECycle = 50L,
  max.MCycle = 10L,
  n.decimal = 5L,
  n.Quadpts = 50L,
  Theta.lim = c(-4, 4),
  Missing = -9,
  ParConstraint = FALSE,
  BiasSE = FALSE,
  D = 1
)
```

Arguments

data	A matrix or data.frame consisting of dichotomous data (1 for correct and 0 for wrong response).
PriorA	A numeric vector with two hyperparameters: the mean and variance of the log-normal distribution for all a parameters. Defaults to c(0, 0.25).
PriorB	A numeric vector with two hyperparameters: the mean and variance of the normal distribution prior for item difficulty (b) parameters. Defaults to c(0, 4).
InitialA	A single numeric value or vector specifying initial values for the item discrimination parameters (a). Defaults to 1. It is recommended to use the point-biserial correlation from Classical Test Theory.
InitialB	A single numeric value or vector specifying initial values for the difficulty parameters (b). Defaults to 0. It is recommended to use the item difficulty index from Classical Test Theory.
Tol	A single numeric value specifying the convergence threshold for E-step cycles. Defaults to 0.01.

max.ECycle	A single integer specifying the maximum number of E-step cycles. Defaults to 50L.
max.MCycle	A single integer specifying the maximum number of M-step cycles. Defaults to 10L.
n.decimal	A single integer specifying the number of decimal places for the output results. Defaults to 5L.
n.Quadpts	A single integer specifying the number of quadrature points per dimension (must be larger than 5). Defaults to 50L.
Theta.lim	A numeric vector of length 2 defining the integration grid range for each dimension. Defaults to c(-4, 4).
Missing	A single numeric value indicating missing elements. Defaults to -9. Cannot be 0 or 1.
ParConstraint	A logical value indicating whether to restrict estimates within a reasonable range. Defaults to FALSE.
BiasSE	A logical value determining whether to estimate SEs directly from the inverted Hessian matrix. Defaults to FALSE.
D	A numeric scale constant (1 or 1.702). Defaults to 1.

Details

The two-parameter logistic (2PL) model proposed by Birnbaum (1968) is defined as:

$$P(x = 1|\Theta, a, b) = \frac{1}{1 + \exp(-D \cdot a \cdot (\Theta - b))}$$

where $x=1$ is the correct response, Θ is the examinee's ability, a is the item discrimination, and b is the difficulty parameter.

Value

A list containing the following components:

- `Est.ItemPars` A data frame with estimates of parameters a and b , along with their standard errors.
- `Est.Theta` A data frame with EAP ability estimates and their standard errors.
- `Loglikelihood` The final log-likelihood value.
- `Iteration` The number of iterations until convergence.
- `EM.Map` The parameter estimation history across iterations.
- `fits.test` Model fit statistics including G^2 , AIC, BIC, and RMSEA.
- `Elapsed.time` Total execution time of the program.
- `InitialValues` The initial values used for item calibration.

Author(s)

Juan Luis Legorreta Torres <jlegorreta2002@yahoo.com.mx>

References

- Baker, F. B., & Kim, S.-H. (2004). *Item Response Theory: Parameter Estimation Techniques* (2nd ed.). Marcel Dekker.
- Birnbaum, A. (1968). Some latent trait models and their use in inferring an examinee's ability. In F. M. Lord & M. R. Novick (Eds.), *Statistical theories of mental test scores* (pp. 395-479). Addison-Wesley.

Examples

```
data(dat01)

# It is recommended to use:
# InitialA = point-biserial correlation (Classical Test Theory)
# InitialB = item difficulty index (Classical Test Theory)

mod_2PL <- irtbem2pl(data = dat01, PriorA = c(0, 0.25), PriorB = c(0, 4),
                    InitialA = 1, InitialB = 0, Tol = 0.01, max.ECycle = 50L,
                    max.MCycle = 10L, n.decimal = 5L, n.Quadpts = 50L,
                    Theta.lim = c(-4, 4), Missing = -9, ParConstraint = FALSE,
                    BiasSE = FALSE, D = 1)

mod_2PL$Est.ItemPars      # show item estimates
mod_2PL$Est.Theta        # show ability estimates
```

 irtchek2pl

Checking user specified input variables

Description

Verifies whether the input variables provided by the user are correct based on the 2PL model specifications. If acceptable, the function formats and returns them as a combined list; otherwise, it throws an error

Usage

```
irtchek2pl(
  Model = "2PL",
  data,
  PriorA = c(0, 0.25),
  PriorB = c(0, 4),
  InitialA = 1,
  InitialB = 0,
  Tol = 0.01,
  max.ECycle = 50L,
  max.MCycle = 10L,
  n.decimal = 5L,
  n.Quadpts = 50L,
```

```

  Theta.lim = c(-4, 4),
  Missing = -9,
  ParConstraint = FALSE,
  BiasSE = FALSE,
  D = 1
)
```

Arguments

Model	A character string declaring the type of item model (e.g., "2PL").
data	A matrix or data.frame consisting of dichotomous data (1 for correct and 0 for wrong response), with missing data coded as in Missing.
PriorA	A numeric vector or matrix specifying the log-normal prior distribution hyperparameters (mean and variance) for item discrimination. Defaults to c(0, 0.25).
PriorB	A numeric vector or matrix specifying the normal prior distribution hyperparameters (mean and variance) for item difficulty. Defaults to c(0, 4).
InitialA	A single numeric value or vector specifying initial values for item discrimination parameters. Defaults to 1.
InitialB	A single numeric value or vector specifying initial values for item difficulty parameters. Defaults to 0.
Tol	A single numeric value specifying the convergence threshold for E-step cycles. Defaults to 0.01.
max.ECycle	A single integer specifying the maximum number of E-step cycles. Defaults to 50L.
max.MCycle	A single integer specifying the maximum number of M-step cycles. Defaults to 10L.
n.decimal	A single integer specifying the number of decimal places for output formatting. Defaults to 5L.
n.Quadpts	A single integer specifying the number of quadrature points per dimension. Defaults to 50L.
Theta.lim	A numeric vector of length 2 defining the integration grid boundaries. Defaults to c(-4, 4).
Missing	A single numeric value indicating missing elements. Defaults to -9. Cannot be 0 or 1.
ParConstraint	A logical value indicating whether parameters are constrained within a reasonable range. Defaults to FALSE.
BiasSE	A logical value determining whether to estimate SEs directly from the inverted Hessian matrix. Defaults to FALSE.
D	A numeric scaling constant (1 or 1.702). Defaults to 1.

Value

A combined list containing formatted data arrays, sample sizes, prior specifications, initial parameter values, and convergence controls.

Author(s)

Juan Luis Legorreta Torres <jlegorreta2002@yahoo.com.mx>

References

Item Response Theory Parameter Estimation Techniques Second Edition, Revised and Expanded
 Frank B. Baker University of Wisconsin Madison, Wisconsin, U.S.A. Seock-Ho Kim The University
 of Georgia Athens, Georgia, u.S.A.

Examples

```
data(dat01)
library(irtbem2pl)
Checking_2PL<-irtchek2pl(Model = "2PL", dat01, D = 1)
```

 LikelihoodInfo2pl

Compute Likelihood Information for the 2PL IRT Model

Description

' Calculates the log-likelihood, deviance, and expected frequencies (f, fz, rz) required for the E-step of the Expectation-Maximization (EM) algorithm under a two-parameter logistic (2PL) model.

Usage

```
LikelihoodInfo2pl(
  data.simple,
  CountNum,
  Model,
  Par.est0,
  n.Quadpts,
  node.Quadpts,
  weight.Quadpts,
  D
)
```

Arguments

<code>data.simple</code>	A numeric matrix representing the simplified unique response patterns.
<code>CountNum</code>	A numeric vector containing the frequencies of each unique response pattern.
<code>Model</code>	A character string declaring the type of IRT model to be evaluated (e.g., "2PL").
<code>Par.est0</code>	A list containing current item parameter estimates (A and B).
<code>n.Quadpts</code>	A single integer indicating the number of quadrature points.
<code>node.Quadpts</code>	A numeric vector containing the nodes of the quadrature grid.
<code>weight.Quadpts</code>	A numeric vector containing the weights of the quadrature grid.
<code>D</code>	A numeric scaling constant (typically 1 or 1.702).

Value

A list containing the following statistical components:

- LH The log-likelihood value of the model given the data.
- Deviance The model deviance statistic calculated as $-2 * LH$.
- f A numeric matrix of expected frequencies per quadrature point.
- fz A numeric matrix of expected correct response frequencies based on P*.
- rz A numeric matrix of expected correct joint frequencies.

 Prob.model

Compute Item Response Probabilities for Various IRT Models

Description

Calculates the probability of a correct response for a given latent trait level (Theta) under specified Item Response Theory (IRT) models.

Usage

```
Prob.model(X, Model, Par.est0, D = 1)
```

Arguments

X	A numeric value or vector representing the latent trait level (Theta) or quadrature node.
Model	A character string specifying the IRT model type. Options include "Rasch", "2PL", "3PL", "4PL", "1PLAG", or "1PLG".
Par.est0	A list containing current item parameter estimates (A, B, C, S, Beta, Alpha, Gamma, depending on the model).
D	A numeric scaling constant (typically 1 or 1.702). Defaults to 1.

Value

A numeric vector or matrix containing the calculated correct response probabilities, bounded between $1e-12$ and $(1 - 1e-12)$ for numerical stability.

Index

* **datasets**

dat01, 2

dat01, 2

irt2pl, 2

irtbem2pl, 4

irtchek2pl, 6

LikelihoodInfo2pl, 8

Prob.model, 9