

Package ‘irtProb’

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Multidimensional Person Item Response Models (IRT)

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Description The irtProb package was mainly developped to compute IRT probability distributions.

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irtProb-package	<i>Utilities and Probability Distributions Related to Multidimensional Person Item Response Models (IRT)</i>
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Description

The `irtProb` package was mainly developed to compute probability distributions in the context of Item Response Theory (IRT). Actually two families of models are taken into account. The first is the family of 1, 2, 3 and 4 parameters logistic functions. The second is a new logistic family adding of 1, 2, 3 and 4 person parameters. With `irtProb` some utilitarian functions are also available. So it is possible to generate response patterns with each family of item response models and other functions are also available to do conversion of item parameters between classical test theory and item response theory (2PL). Maximum likelihood and Maximum a posteriori estimation function of the multidimensional person parameters are also available.

Details

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References

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- Plumlee, L B. (1954). The predicted and observed effect of chance success on multiple-choice test validity. *Psychometrika*, 19(1), 65-70.

See Also

Other packages are also very useful to manipulate IRT objects. The R psychometric view is instructive at this point. See <http://cran.stat.sfu.ca/web/views/Psychometrics.html> for further details.

4pl

One, Two, Three and Four Parameters Logistic Distributions

Description

Density, distribution function, quantile function and random generation for the one, two, three and four parameters logistic distributions.

Usage

```
p4pl(theta = 0, a = 1, b = 0, c = 0, d = 1, lower.tail = TRUE,
log.p = FALSE)
```

```
d4pl(theta = 0, a = 1, b = 0, c = 0, d = 1,
log.p = FALSE)
```

```
q4pl(p = 0.05, a = 1, b = 0, c = 0, d = 1, lower.tail = TRUE,
log.p = FALSE)
```

```
r4pl(N = 100, a = 1, b = 0, c = 0, d = 1)
```

Arguments

N	numeric; number of observations.
p	numeric; vector of probability.
theta	numeric; vector of person proficiency levels scaled on a normal z score.
a	numeric; positive vector of item discrimination parameters.
b	numeric; vector of item difficulty parameters.
c	numeric; positive vector of item pseudo-guessing parameters (a probability between 0 and 1).
d	numeric; positive vector of item inattention parameters (a probability between 0 and 1).
lower.tail	logical; if TRUE (default), probabilities are $P(X_j \leq x_{ij})$, otherwise, $P(X_j > x_{ij})$.
log.p	logical; if TRUE probabilities p are given as log(p).

Details

The 4 parameters logistic distribution (cdf) is equal to:

$$P(x_{ij} = 1 | \theta_j, a_i, b_i, c_i, d_i) = c_i + \frac{d_i - c_i}{1 + e^{-Da_i(\theta_j - b_i)}}$$

where the parameters are defined in the section arguments and i and j are respectively the items and the persons indices. A normal version of the 4PL model was described by McDonald (1967, p. 67), Barton and Lord (1981), like Hambleton and Swaminathan (1985, p. 48-50).

Value

p4pl	numeric; gives the distribution function (cdf).
d4pl	numeric; gives the density (derivative of p4pl).
q4pl	numeric; gives the quantile function (inverse of p4pl).
r4pl	numeric; generates theta random deviates.

Note

Code inspired by the pnorm function structure from the R base package.

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References

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- Lord, F. M. and Novick, M. R. (1968). *Statistical theories of mental test scores, 2nd edition*. Reading, Massacuset: Addison-Wesley.
- McDonald, R. P. (1967). Non-linear factor analysis. *Psychometric Monographs*, 15.

See Also

[gr4pl](#), [ggr4pl](#), [ctt2irt](#), [irt2ctt](#)

Examples

```
## .....
# probability of a correct response
p4pl(theta = 3, b = 0)

# Verification of the approximation of N(0,1) by a logistic (D=1.702)
a <- 1; b <- 0; c <- 0; d <- 1; theta <- seq(-4, 4, length = 100)

# D constant 1.702 gives an approximation of a N(0,1) by a logistic
prob.irt <- p4pl(theta, a*1.702, b, c, d)
prob.norm <- pnorm(theta, 0, 1)
plot(theta, prob.irt)
lines(theta, prob.norm, col = "red")

# Maximal difference between the two functions: less than 0.01
max(prob.irt - prob.norm)

# Recovery of the value of the probability of a correct response p4pl()
# from the quantile value q4pl()
p4pl(theta = q4pl(p = 0.20))

# Recovery of the quantile value from the probability of a correct
# response
q4pl(p=p4pl(theta=3))

# Density Functions [derivative of p4pl()]
d4pl(theta = 3, a = 1.702)
theta <- seq(-4, 4, length = 100)
a <- 3.702; b <- 0; c <- 0; d <- 1
density <- d4pl(theta = theta, a = a, b = b, c = c, d = d)
label <- expression("Density - First Derivative")
plot(theta, density, ylab = label, col = 1, type = "l")
lines(theta, dnorm(x = theta, sd = 1.702/a), col = "red", type = "l")

## Generation of proficiency levels from r4pl() according to a N(0,1)
data <- r4pl(N = 10000, a = 1.702, b = 0, c = 0, d = 1)
```

```
c(mean = mean(data), sd = sd(data))
## .....
```

checkAdequation *Function to Check the Adequation of the Second Derivatives*

Description

Check the adequation of the second derivatives (hessian) for computation of variance and covariance. Use inside the function `m4plEstimateMore` to assure that computations can be applied to this second derivative. Problems encountered can be of not positive definiteness, singular matrix, diagonal not completely positive. In these cases inversion of the matrix is not possible or variances cannot be computed from the inverse of the diagonal.

Usage

```
checkAdequation(x)
```

Arguments

`x` matrix: second derivative (hessian).

Value

`isNumbers` logical: check if the elements of the `x` matrix are all numerics.
`correctClass` logical: check if the the `x` matrix is of class `matrix`.
`squareMatrix` logical: check if the the `x` matrix is square.
`diagPositive` logical: check if the elements of the `x` matrix are all positive and > 0 .
`positiveDefinite` logical: check if the the `x` matrix is `positiveDefinite`.
`nonSingular` logical: check if the the `x` matrix is `nonSingular`.

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References

Seber, G. E. A. F. (2008). *A matrix handbook for statisticians*. New York, New Jersey: Wiley.

See Also

[eigen](#), [det](#), [diag](#)

Examples

```

## Complete adequation of the matrix
## .....
x <- matrix(c(4.867054, 16.66902, 16.669023, 107.36390), ncol=2)
checkAdequation(x)
all(checkAdequation(x))
eigen(x)$values
det(x)
diag(x)
## .....

## Not positiveDefinite matrix
## .....
x <- matrix(1:4, ncol=2)
checkAdequation(x)
all(checkAdequation(x))
eigen(x)$values
det(x)
diag(x)
## .....

## More problems
## .....
x <- matrix(c("Inf",2,5,10), ncol=2)
checkAdequation(x)
all(checkAdequation(x))
det(x)
diag(x)
# eigen(x)$values
x <- matrix(c("NaN",2,5,10), ncol=2)
checkAdequation(x)
all(checkAdequation(x))
det(x)
diag(x)
# eigen(x)$values
## .....

```

Description

ctt2irt and irt2ctt are converter functions to change the parametrization of item parameters from and to classical test theory (difficulty and discrimination parameters) and item response theory (difficulty and discrimination parameters). Consequently, the conversion is only valid between ctt and 2 parameters logistic or normal models.

Usage

```
ctt2irt(rpbis = 0.7071068, difficulty = 0.5)

irt2ctt(a = 1, b = 0, c = 0, d = 1, model = "LOGISTIC")
```

Arguments

rpbis	numeric; vector of discrimination parameters: point biserial correlation between the item response and the total score.
difficulty	vector of difficulty parameters: proportion of corrected responses.
a	numeric; vector of discrimination parameters.
b	numeric; vector of difficulty parameters.
c	numeric; vector of pseudo-guessing parameters (not used for the moment).
d	numeric; vector of inattention parameters (not used for the moment).
model	character; if NORMAL the constant D (1.702) is used. Default to LOGISTIC with constant D=1.

Details

Eventually the 3 and 4 parameters logistic and normal models will be taken in account according to Urry approximation (1974).

Value

For ctt2irt
note	character; warnings about the use of the c and d item parameters.
normal.parameters	numeric; vector returning difficulty b and discrimination a parameters from the normal model.
irt.parameters	numeric; vector returning difficulty b and discrimination a parameters from the logistic model.
For irt2ctt
note	character; warnings about the use of the c and d item parameters.
normal.parameters	numeric; vector returning difficulty p and discrimination rpbis parameters from the normal model.
irt.parameters	numeric; vector returning difficulty p and discrimination rpbis parameters from the logistic model.

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References

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- Urry, V. W. (1974). Approximations to item parameters of mental tests models and their uses. *Educational and psychological measurement, 34*, 253-269.

See Also

[gr4pl](#), [ggr4pl](#), [ctt2irt](#), [irt2ctt](#)

Examples

```
## .....
# Values of p and rbis according to de a, b, c and d values
# MODEL means that item parameters are from a NORMAL or LOGISTIC model
# type
irt2ctt()
nItems <- 5
b <- seq(-3, 3, length=nItems)
a <- rep(1, nItems)
c <- rep(0, nItems)
d <- rep(1, nItems)

# Difference between classical item parameters and IRT ones
irt2ctt(b=b,a=a,c=c,d=d,model="LOGISTIC")
irt2ctt(b=b,a=a,c=c,d=d,model="NORMAL")

# Values of a and b according p and rpbis
ctt2irt()

# Verification of the recovery of original ctt item parameters
nItems <- 5
p <- seq(0.10, 0.90, length=nItems)
rpbis <- seq(0.50, 0.95, length=nItems)
irt <- ctt2irt(dif=p,rpbis=rpbis)
clas <- irt2ctt(b=irt$normal[2],a=irt$normal[1],model="NORMAL")
round(c(NORMAL=irt$normal, IRT=irt$irt, CTT=clas$normal), 3)
## .....
```

Description

Three points first and second derivatives numerical approximation used with the `m4plEstimateMore` function.

Usage

```
fprime( x, FUN = "FP", h = 0.001, names = paste("x", c(1:length(x)),
sep = ""))
fsecond(x, FUN = "FP", h = 0.001, names = paste("x", c(1:length(x)),
sep = ""))
```

Arguments

x	numeric; vector of values at which the derivation is to be done.
FUN	function; function to derive.
h	numeric; neighbouring value.
names	character; names given to each results. DEFAULT to the existing names of the vector x.

Details

This function could be used for numerical derivation in general, but is dedicated to be used internally by `m4plEstimateMore`. For other general purposes `D`, `deriv` and `deriv3` are preferred.

Value

fprime	numeric; vector of first derivatives.
fsecond	numeric; matrix of second derivatives.

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References

Press, W. H., Vetterling, W. T., Teukolsky, S. A. and Flannery, B. P. (2002). *Numerical recipees in C++*. *The art of scientific computing, 2nd edition*. Cambridge, United Kingdom: Cambridge University press.

Yakowitz, S. and Szidarovszky, F. (1986). *An introduction to numerical computations*. New York, New Jersey: MacMilla.

See Also

[D](#), [deriv](#) and [deriv3](#)

Examples

```
## .....
test <- function(x) 2*x+5
test( x=0)
fprime( x=0, FUN=test)
fsecond(x=0, FUN=test)
## .....
test2 <- function(x) 2*(x[1]*x[2])+5
test2( x=c(0,0))
fprime( x=c(0,0), FUN=test2)
fsecond(x=c(0,0), FUN=test2)
```

graphics

Graphic Functions to Illustrate Response Curves and Parameter Estimation

Description

Graphic functions to illustrate response curves and parameter estimation.

Usage

```
PCC(theta = 0, S = 0, C = 0, D = 0,
     s = 1/1.702, b = seq(-5, 5, length = 300), c = 0,
     d = 1, groups = TRUE, ID = "ID",
     main = "Person Characteristic Curve",
     xlab = "Item Difficulty Parameter (b)",
     ylab = "P(x = 1)", type = c("g", "a"))
```

Arguments

theta	numeric; vector of person proficiency (θ) levels scaled on a normal z score.
S	numeric: positive vector of personal fluctuation parameters (σ).
C	numeric: positive vector of personal pseudo-guessing parameters (χ , a probability between 0 and 1).
D	numeric: positive vector of personal inattention parameters (δ , a probability between 0 and 1).
s	numeric: vector of item fluctuation parameter or the inverse of item discrimination ($s=1/a$).
b	numeric: vector of item discrimination parameter.
c	numeric: vector of item pseudo-guessing parameter.
d	numeric: vector of item inattention parameter.
ID	character: curves identification information displayed ("ID", "ALL", "THETA2 or NULL)

groups	logical: default to TRUE. If TRUE, Lattice xyplot by groups. If FALSE, xyplot with shingles.
main	character: first line of main title.
xlab	character: label of x axis.
ylab	character: label of y axis.
type	character: type of xyplot graphic. One of the following: "p", "l", "h", "b", "o", "s", "S", "r", "a", "g", "smooth".

Value

PCC returns a list:

graphic	trellis object: figures for each subject (group or shingle representation).
probability	data.frame: item snd person parameters, like th eprobability of a correct response.

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Examples

```
## PCC curves grouped on a single figure
res1 <- PCC(theta=c(-2,-2,-2),S=0, C=c(0.0, 0.1, 0.6), D=0.2,
           b=seq(-5,5,length=3000), ID=NULL, groups=TRUE,
           type=c("g","a"))
res1

## PCC curves shingled on a single figure for each subject
res2 <- PCC(theta=c(-2,-1,0),S=c(4.0,0.0, 1.0), C=c(0.0, 0.1, 0.6), D=0.2,
           b=seq(-5,5,length=3000), ID=NULL, groups=FALSE,
           type=c("g","a"))
res2
```

likelihoodCurve

Functions to Graph m4pl Likelihood Curves

Description

likelihoodCurve and groupLikelihoodCurve are used to graph the likelihood function curves according to the only theta, theta anc pseudo-guessing, theta and fluctuation, like theta and inattention m4pl models: only two simultaneous person parameters are taken in account.

Usage

```
likelihoodCurve(x, s, b, c, d,
               limitT = c(min = -4, max = 4), limitS = c(min = 0, max = 4),
               limitC = c(min = 0, max = 1), limitD = c(min = 0, max = 1),
               grain      = 150, annotate = TRUE,
               logLikelihood = FALSE, color = TRUE,
               main       = "Likelihood Curve",
               xlab      = expression(theta), ylab = NULL, zlab = "P(X)",
               type      = "levelplot", m = 0)

groupLikelihoodCurves(plotT, plotS, plotC, plotD, main=NULL, cex=0.7)
```

Arguments

x	numeric: binary (0,1) response pattern.
s	numeric: vector of inverse a discrimination item parameters.
b	numeric: vector of b difficulty item parameters.
c	numeric: vector of c pseudo-guessing item parameters.
d	numeric: vector of d inattention item parameters.
limitT	numeric: minimum and maximum of the proficiency person parameter used for the x axis.
limitS	numeric: minimum and maximum of the fluctuation person parameter used for the y axis.
limitC	numeric: minimum and maximum of the pseudo-guessing person parameter used for the y axis.
limitD	numeric: minimum and maximum of the inattention person parameter used for the y axis.
grain	numeric: number of theta values used to compute pattern distribution probability.
annotate	logical: does annotation is applied to the graphs?
logLikelihood	numeric: data.frame of the log likelihood of the studied models.
color	logical: does color is applied to contourplot or wireframe.
main	character: main title.
xlab	character: x axis label.
ylab	character: y axis label.
zlab	character: z axis label.
type	character: type of 3D plot ("levelplot", "contourplot" or "wireframe").
m	numeric: mean of the a priori probability distribution.
plotT	trellis: 2D theta likelihood curve.
plotS	trellis: 3D theta * S likelihood curve.
plotC	trellis: 3D theta * C likelihood curve.
plotD	trellis: 3D theta * D likelihood curve.
cex	numeric: zaxis label size.

Value

likelihoodCurve

plotT trellis: theta likelihood functions curves.

plotS trellis: theta * S likelihood functions curves.

plotC trellis: theta * C likelihood functions curves.

plotD trellis: theta * D likelihood functions curves.

parameters numeric: list of data.frame of person parameters for each model studied. Each element of the list shows estimation with different a priori probability distributions (uniform, normal and none).

logLikelihood numeric: data.frame of the log likelihood for each model studied.

groupLikelihoodCurves

graphic graphic: all the likelihood functions curves are displayed.

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Examples

```
## SIMULATION OF A RESPONSE PATTERN WITH 60 ITEMS
nItems <- 60
a     <- rep(1.702,nItems); b <- seq(-4,4,length=nItems)
c     <- rep(0,nItems);     d <- rep(1,nItems)
nSubjects <- 1
theta   <- -1
S       <- 0.0
C       <- 0.5
D       <- 0.0

set.seed(seed = 100)
x       <- ggrm4pl(n=nItems, rep=1,
                  theta=theta, S=S, C=C, D=D,
                  s=1/a, b=b,c=c,d=d)

## Likelihood curves, person parameters estimates
# and log likelihood of models graphed
test <- likelihoodCurve(x=x, s=1/a, b=b, c=c, d=d, color=TRUE,
                       main="Likelihood Curve",
                       xlab=expression(theta), ylab=NULL, zlab="P(X)",
                       type="wireframe" , grain=50, limitD=c(0,1),
                       logLikelihood=FALSE, annotate=TRUE )

# Contentd of the object test
test$plotT
```

```

test$plotC
test$plotS
test$plotD
test$par
round(test$logLikelihood,2)

## Graph of all the likelihood function curves
groupLikelihoodCurves(test$plotT, test$plotS, test$plotC, test$plotD,
                        main=NULL, cex=0.7)

```

m4pl

Multidimensional One, Two, Three and Four Person Parameters Logistic Distributions

Description

Density, distribution function, quantile function and random generation for the multidimensional one, two, three and four person parameters logistic distributions.

Usage

```

pm4pl(theta = 0, S = 0, C = 0, D = 0, s = 1/1.702, b = 0, c = 0, d = 1,
       lower.tail = TRUE, log.p = FALSE)

dm4pl(theta = 0, S = rep(0,length(theta)), C = rep(0,length(theta)),
       D = rep(0,length(theta)), b = 0, s = 1/1.702, c = 0, d = 1, log.p = FALSE)

qm4pl(p = 0.05, S = 0, C = 0, D = 0, s = 1/1.702, b = 0, c = 0, d = 1,
       lower.tail = TRUE, log.p = FALSE)

rm4pl(N = 100, S = 0, C = 0, D = 0, s = 1/1.702, b = 0, c = 0, d = 1)

```

Arguments

theta	numeric; vector of person proficiency (θ) levels scaled on a normal z score.
S	numeric; positive vector of personal fluctuation parameters (σ).
C	numeric; positive vector of personal pseudo-guessing parameters (χ , a probability between 0 and 1).
D	numeric; positive vector of personal inattention parameters (δ , a probability between 0 and 1).
N	numeric; number of observations.
p	numeric; vector of probability.
s	numeric; positive vector of item fluctuation parameters.
b	numeric; vector of item difficulty parameters.

c	numeric; positive vector of item pseudo-guessing parameters (a probability between 0 and 1).
d	numeric; positive vector of item inattention parameters (a probability between 0 and 1).
lower.tail	logical; if TRUE (default), probabilities are $P(X_j \leq x_{ij})$, otherwise, $P(X_j > x_{ij})$.
log.p	logical; if TRUE, probabilities p are given as log(p).

Details

The multidimensional 4 persons parameters logistic distribution (cdf) is equal to:

$$P(x_{ij} = 1 | \theta_j, \sigma_j, \chi_j, \delta_j, s_i, b_i, c_i, d_i) = (\chi_j + c_i) + \frac{(d_i - \delta_j) - (\chi_j + c_i)}{1 + e^{\frac{-D a_i (\theta_j - b_i)}{\sqrt{\sigma_j^2 + s_i^2}}}}$$

where the parameters are defined in the section arguments and i and j are respectively the items and the persons indices. The σ_j , χ_j and δ_j parameters are respectively the personal fluctuation, pseudo-guessing and inattention parameters. The multidimensional 4 persons parameters logistic model (M4PL) was described by Raiche, Magis and Blais (2008; Raiche, Magis and Beland, 2009; Raiche, Blais and Magis, 2009).

Value

pm4pl	numeric; gives the distribution function (cdf).
dm4pl	numeric; gives the density (derivative of p4pl).
qm4pl	numeric; gives the quantile function (inverse of p4pl).
rm4pl	numeric; generates theta random deviates.

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References

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See Also

[grm4pl](#), [ggrm4pl](#), [pggrm4pl](#)

Examples

```
## .....
# Approximation of p4pl() by pm4pl()
theta <- 0
S <- 0; C <- 0; D <- 0
a <- 1.702; s <- sqrt(1/a^2); b <- 0; c <- 0; d <- 1
p.4pl <- p4pl(theta,a=a,b,c,d);
p.m4pl <- pm4pl(theta,S,C,D,s,b,c,d)
print(c(p4pl=p.4pl, m4pl=p.m4pl))

# Comparison of p4pl() and pm4pl() according to diverse values of theta
# while person parameters vary
theta <- seq(-4,4,length=100); N <- length(theta)
S <- rep(0.9,N); C <- rep(0,N); D <- rep(0.9,N)
a <- 1.702; s <- 1/1.702
p.4pl <- p4pl(theta=theta, a=a, b=b, c=c, d=d)
p.m4pl <- pm4pl(theta=theta, S=S, C=C, D=D, s=s, b=b, c=c, d=d)
print(c(difference.maximale = max(p.4pl - p.m4pl)))
round(rbind(theta=theta, p4pl=p.4pl, m4pl=p.m4pl, dif=p.4pl-p.m4pl),3)
plot(theta,p.4pl,type="l", col="black", ylab="Probability")
lines(theta,p.m4pl,col="red"); max(p.4pl-p.m4pl)

# Recovery of probability by quantile
pm4pl(theta=3,b=0); pm4pl(theta=qm4pl(p=0.20))

# Density function dm4pl()
# Comparison 01 between d4pl() and dm4pl()
theta <- seq(-4,4, length=100)
# theta <- 0 # We can also experiment with an unique value of theta
N <- length(theta)
S <- rep(0,N); C <- rep(0,N); D <- rep(0,N)
a <- 1.702
d.4pl <- d4pl(theta=theta,a=a)
d.m4pl <- dm4pl(theta=theta,S=0,s=1/a)
stats <- round(cbind(theta=theta, d4pl=d.4pl, m4pl=d.m4pl, dif=d.4pl-d.m4pl),3)
print(stats)
print(max(d.4pl - d.m4pl))
plot(theta,d.4pl,type="l", col="black", ylab="Density")
lines(theta,d.m4pl,col="red")

# Comparison 02 between d4pl() and dm4pl()
theta <- seq(-4,4, length=10)
N <- length(theta)
S <- rep(.3,N); C <- rep(0,N); D <- rep(0,N)
a <- 1.702
d.4pl <- d4pl(theta=theta,a=a)
d.m4pl <- dm4pl(theta=theta, S=S, C=C, D=D, s=1/a)
stats <- round(cbind(theta=theta, d4pl=d.4pl, m4pl=d.m4pl, dif=d.4pl-d.m4pl),3)
```

```

print(stats)
print(max(d.4pl - d.m4pl))
plot(theta,d.4pl,type="l", col="black", ylab="Density")
lines(theta,d.m4pl,col="red")

# Comparison of q4pl and qm4pl
# followed by recovery of quantiles
pm4pl(theta=1, ); p4pl(theta=1, a=1.702)
qm4pl(p=0.99,); q4pl(p=0.99, a=1.702)
qm4pl(pm4pl(theta=1)); q4pl(p4pl(theta=1, a=1.702), a=1.702)
qm4pl(p=pm4pl(theta=3))
qm4pl(p=seq(0.01,0.99, length=10))

# Generation of theta values by rm4pl()
# ... Exemple 01 - A 4pl() equivalent distribution must be recovered when a=1.702
res <- rm4pl(N=1000)
stats <- c(mean=sapply(res, mean), sd=sapply(res, sd), skewness=sapply(res, skewness),
           kurtosis=3-sapply(res, kurtosis))
print(stats)
# pdf of this distribution
theta <- seq(-4,4,length=100); C=rep(0,N); D=rep(0,N)
density <- dm4pl(theta,C=C,D=D)
plot(theta, density, type="l")

# ... Exemple 02 - Distribution with D != 0
require(moments)
S <- 1/1.702
B <- 0
C <- 0.00
D <- 0.90
res <- rm4pl(N=1000, S=S, C=C, D=D)
stats <- c(mean=sapply(res, mean), sd=sapply(res, sd), skewness=sapply(res, skewness),
           kurtosis=3-sapply(res, kurtosis))
print(stats)
# pdf of this distribution
theta <- seq(-4,4,length=100)
density <- dm4pl(theta, S=S, C=C, D=D)
print(c(max=max(density)))
plot(theta, density, type="l")
## .....

```

Description

Show all the information about the estimation of all the possible m4pl models for each subjects.

Usage

```
m4plModelShow(x, ...)
```

Arguments

x data.frame: a matrix of binary 0-1 item responses.
 ... varying: parameters to be passed to the m4plPersonParameters function.

Value

ID integer: subject identifier.
 MODEL charavter: model identification (T,TS,TC,TD,TSC,TSD,TCD or TSCD)
 LL numeric: loglikelihood.
 AIC numeric: Akaike information criteria.
 BIC numeric: Bayes (Schwartz) information criteria.
 T numeric: theta parameter value.
 SeT numeric: theta parameter theoretical standard error.
 S numeric: person fluctuation parameter value.
 SeS numeric: person fluctuation theoretical standard error
 C numeric: person pseudo-guessing parameter value.
 SeC numeric: person pseudo-guessing theoretical standard error
 D numeric: person inattention parameter value.
 SeD numeric: person inattention theoretical standard error

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Raiche, G., Magis, D. and Beland, S. (2009). *La correction du resultat d'un etudiant en presence de tentatives de fraudes*. Communication presentee a l'Universite du Quebec a Montreal. Retrieved from <http://www.camri.uqam.ca/camri/camriBase/>

Raiche, G., Magis, D. and Blais, J.-G. (2008). *Multidimensional item response theory models integrating additional inattention, pseudo-guessing, and discrimination person parameters*. Communication at the annual international Psychometric Society meeting, Durham, New Hamshire. Retrieved from <http://www.camri.uqam.ca/camri/camriBase/>

See Also

[m4plPersonParameters](#)

Examples

```
## GENERATION OF VECTORS OF RESPONSES
# NOTE THE USUAL PARAMETRIZATION OF THE ITEM DISCRIMINATION,
# THE VALUE OF THE PERSONNAL FLUCTUATION FIXED AT 0,
# AND THE VALUE OF THE PERSONNAL PSEUDO-GUESSING FIXED AT 0.30.
# IT COULD BE TYPICAL OF PLAGIARISM BEHAVIOR.
nItems <- 40
a      <- rep(1.702,nItems); b <- seq(-5,5,length=nItems)
c      <- rep(0,nItems); d <- rep(1,nItems)
nSubjects <- 1; rep <- 100
theta  <- seq(-1,-1,length=nSubjects)
S      <- runif(n=nSubjects,min=0.0,max=0.0)
C      <- runif(n=nSubjects,min=0.3,max=0.3)
D      <- runif(n=nSubjects,min=0.0,max=0.0)
set.seed(seed = 100)
X      <- ggrm4pl(n=nItems, rep=rep,
                 theta=theta, S=S, C=C, D=D,
                 s=1/a, b=b,c=c,d=d)

## Results for each subjects for each models
essai <- m4plModelShow(X, b=b, s=1/a, c=c, d=d, m=0, prior="uniform")

## Mean results for some speficic models
median(essai[which(essai$MODEL == "TSCD"),]$SeT, na.rm=TRUE)
mean(  essai[which(essai$MODEL == "TSCD"),]$SeT, na.rm=TRUE)
mean(  essai[which(essai$MODEL == "TD"),]$SeT, na.rm=TRUE)
sd(    essai[which(essai$MODEL == "TD"),]$T, na.rm=TRUE)

## Result for each models for the first subject
essai[which(essai$ID == 1),]
max(essai[which(essai$ID == 1),]$LL)

## Difference between the estimated values with the T and TSCD models for the
## first subject
essai[which(essai$ID == 1 & essai$MODEL == "T"),]$T
- essai[which(essai$ID == 1 & essai$MODEL == "TSCD"),]$T
```

Description

Summary of the results of estimation with the m4pl models.

Usage

```

m4plSummary(      X, ...)

m4plMoreSummary( x, out = "result", thetaInitial = NULL)

m4plNoMoreSummary(x)

```

Arguments

X	data.frame or list: if a list results from m4plPersonParameters function, if a data.frame, any all numeric data.frame.
x	list: result from m4plPersonParameters with more set to TRUE.
out	character: if out="results", the output is for each subjects. If out="report", statistics on all results are computed.
thetaInitial	numeric: if initial theta valeus are used the error of estimation is also reported.
...	generic: to be able to pass parameters from the m4plMoreSummary function.

Value

.....

m4plSummary

.....

The result of m4plSummary depends of the out condition and the class of X. If X is a data.frame, the function m4plNoMoreSummary is called and a data.frame with 2 rows is returned: mean and sd rows.

If out="result" and X is a list, the function m4plMoreSummary is called and a data.frame with the mean of the parameters and their theoretical standard errors is returned:

If out="report" and X is a list, m4plMoreSummary is called and the following list taking in account each parameters is returned:

parameters	data.frame: with mean, median, sd an N observations for each parameters.
se	data.frame: with mean, median, sd an N observations for the theoretical values of the standard error for each parameters.
logLikelihood	data.frame: mean, median, sd an N observations loglikelihood, AIC and BIC for the model.
eCorrelation	matrix: empirical correlations between the parameters.
tCorrelation	matrix: theoretical correlations between the parameters.

.....

m4plNoMoreSummary

.....

A data.frame with 2 rows is returned: mean and sd rows.

.....
 m4plMoreSummary

.....
 All other outputs from the m4plSummary function.

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See Also

[m4plPersonParameters](#)

Examples

```
## GENERATION OF VECTORS OF RESPONSE
# NOTE THE USUAL PARAMETRIZATION OF THE ITEM DISCRIMINATION,
# THE VALUE OF THE PERSONNAL FLUCTUATION FIXED AT 0,
# AND THE VALUE OF THE PERSONNAL PSEUDO-GUESSING FIXED AT 0.30.
# IT COULD BE TYPICAL OF PLAGIARISM BEHAVIOR.
nSubjects <- 1
nItems <- 40
a <- rep(1.702,nItems); b <- seq(-5,5,length=nItems)
c <- rep(0,nItems); d <- rep(1,nItems)
theta <- seq(-2,-2,length=nSubjects)
S <- runif(n=nSubjects,min=0.0,max=0.0)
C <- runif(n=nSubjects,min=0.3,max=0.3)
D <- runif(n=nSubjects,min=0.0,max=0.0)
rep <- 100
set.seed(seed = 10)
X <- ggrm4pl(n=nItems, rep=rep,
            theta=theta, S=S, C=C, D=D,
```

```

s=1/a, b=b,c=c,d=d)

## Estimation of the model integrating the T and the C parameters
model <- "C"
test <- m4plPersonParameters(x=X, b=b, s=1/a, c=c, d=d, m=0, model=model,
                             prior="uniform", more=TRUE)

## Summary of the preceding model (report and first 5 subjects)
essai <- m4plSummary(X=test, out="report")
# Rounding the result of the list to two decimals
lapply(essai, round, 2)
essai <- m4plSummary(X=test, out="result")[1:5,]
lapply(essai, round, 2)
essai <- m4plSummary(X=test, out="report", thetaInitial=theta)
lapply(essai, round, 2)
essai <- m4plSummary(X=test, out="result", thetaInitial=theta)[1:5,]
lapply(essai, round, 2)

## Results directly from m4plMoreSummary()
essai <- m4plMoreSummary(x=test, out="report")
lapply(essai, round, 2)
essai <- m4plMoreSummary(x=test, out="result")[1:5,]
round(essai, 2)

## To obtain more general statistics on the result report
essai <- m4plMoreSummary(x=test, out="result")
m4plNoMoreSummary(essai)
summary(m4plMoreSummary(x=test, out="result"))

```

modelChoose

Functions For Choosing The m4pl Best Model(s)

Description

Functions to help to choose the best models from the m4pl person response models family. The function `meanModels` gives the mean of selected and available statistics from a `m4plModelShow` result. The function `modelChoose` shows which model(s) are chosen for each subject, while the function `modelChooseAdd` adds a supplementary logical variable indicating which model(s) are chosen for each subject to the data.frame returned previously by a `m4plModelShow` call .

Usage

```

meanModels(  modelShow, statistics=c("T","S"))

modelChoose(  modelShow, criteria = "BIC", tol = 0.2)

modelChooseAdd(modelShow, criteria="LL")

```

Arguments

modelShow	data.frame: result returned by a m4plModelShow call.
criteria	character: criteria used to choose between models (LL, AIC or BIC).
tol	numeric: tolerance around the choose criteria, so that more models can be considered.
statistics	character: a vector of variables for which means of statistics from m4plModelShow will be computed.

Details

A tolerance varying between 0.10 and 0.20 is suggested. Lower the value, less models are chosen.

Value

meanModels	data.frame: this function return a data.frame of means for each choosen variables.
modelChoose	list: return a list of the models(s) choosen for each subject.
modelChooseAdd	data.frame: return a data.frame adding a logical indicator of the choosen model(s).

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Raiche, G., Magis, D. and Beland, S. (2009). *La correction du resultat d'un etudiant en presence de tentatives de fraudes*. Communication presentee a l'Universite du Quebec a Montreal. Retrieved from <http://www.camri.uqam.ca/camri/camriBase/>

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See Also

[m4plModelShow](#)

Examples

```

## GENERATION OF VECTORS OF RESPONSE
# NOTE THE USUAL PARAMETRIZATION OF THE ITEM DISCRIMINATION,
# THE VALUE OF THE PERSONAL FLUCTUATION FIXED AT 0,
# AND THE VALUE OF THE PERSONAL PSEUDO-GUESSING FIXED AT 0.30.
# IT COULD BE TYPICAL OF PLAGIARISM BEHAVIOR.
nItems <- 40
a <- rep(1.702,nItems); b <- seq(-5,5,length=nItems)
c <- rep(0,nItems); d <- rep(1,nItems)
nSubjects <- 1; rep <- 100
theta <- seq(-1,-1,length=nSubjects)
S <- runif(n=nSubjects,min=0.0,max=0.0)
C <- runif(n=nSubjects,min=0.3,max=0.3)
D <- runif(n=nSubjects,min=0,max=0)
set.seed(seed = 100)
X <- ggrm4pl(n=nItems, rep=rep,
            theta=theta, S=S, C=C, D=D,
            s=1/a, b=b,c=c,d=d)

## Results for each subjects for each models
essai <- m4plModelShow(X, b=b, s=1/a, c=c, d=d, m=0, prior="uniform")

## Means of choosen variables from m4plModleShow previous call
round(meanModels(essai, statistic=c("LL","BIC","T","C")), 2)

## Which model(s) are the best for each subject (LL criteria)
res <- modelChoose(essai, criteria = "LL", tol = 0.2); res

## Which model(s) are the best for each of the first 20 subjects (BIC criteria)
res <- modelChoose(essai[which(essai$ID < 20) ,], criteria="BIC"); res

## A look at the 15th subject parameters estimation for each models
essai[which(essai$ID == 15) ,]

## Add the logical critLL variable to the data frame
criteria <- "LL"
res1 <- modelChooseAdd(essai, criteria=criteria)
# Create a charcater string composed from "crit" and criteria
crit <- paste("crit",criteria,sep="")
# To Show only the lines where the models is choosen according to critLL
res2 <- res1[which(res1[crit] == TRUE),]; mean(res2$T);sd(res2$T,na.rm=TRUE);res2
# Give the mean for choosen variables from m4plModelShow
meanModels(essai, statistic=c("LL","BIC","T","SeT","S","C","D"))
# Tabulate only the choosen models
table(res2$MODEL)
# Show the information for the subject for which the model TSCD was choosen
res2[which(res2$MODEL == "TSCD") ,]
# Show only the results for the 5th subject, the with the TSCD model choosen
res1[which(res1$ID == 5) ,]
# Same, but without critLL
essai[which(essai$ID == 5) ,]

```

```

## Simulation with cheating
# High proficiency students responding at random to 20% of the first items
# easiest ones)
XHPProficiency          <- X
pourcHasard             <- 0.20; nHasard <- abs(dim(X)[2]*pourcHasard)
XHPProficiency[,1:nHasard] <- rbinom(dim(X)[1]*nHasard, 1, 0.5)
XHPProficiency          <- m4plModelShow(XHPProficiency, b=b, s=1/a, c=c, d=d,
                                         m=0, prior="uniform")

XHPProficiency          <- modelChooseAdd(XHPProficiency, criteria=criteria)
XHPProficiency          <- XHPProficiency[which(XHPProficiency$critLL == TRUE),]
mean(XHPProficiency$T);sd(XHPProficiency$T,na.rm=TRUE);XHPProficiency[1:10,]
meanModels(XHPProficiency, statistic=c("LL","BIC","T","SeT","S","C","D"))
table(XHPProficiency$MODEL)

# Low proficiency students responding at random to 20% of the last items
# (more difficult ones)
XLProficiency           <- X
pourcHasard             <- 0.20
nHasard                 <- abs(dim(X)[2]*pourcHasard)
XLProficiency[, (nItems-nHasard+1):nItems] <- rbinom(dim(X)[1]*nHasard, 1, 0.5)
XLProficiency           <- m4plModelShow(XLProficiency, b=b,
                                         s=1/a, c=c, d=d, m=0, prior="uniform")

XLProficiency           <- modelChooseAdd(XLProficiency,
                                         criteria=criteria)

XLProficiency <- XLProficiency[which(XLProficiency$critLL == TRUE),]
mean(XLProficiency$T);sd(XLProficiency$T,na.rm=TRUE);XLProficiency[1:10,]
meanModels(XLProficiency, statistic=c("LL","BIC","T","SeT","S","C","D"))
table(XLProficiency$MODEL)

# High proficiency students giving incorrect responses to 20% of the first items
# (easiest ones)
XHPProficiency          <- X
pourcCheat              <- 0.20; nCheat <- abs(dim(X)[2]*pourcCheat)
XHPProficiency[,1:nCheat] <- rep(0, dim(X)[1]*dim(X)[2]*pourcCheat)
XHPProficiency          <- m4plModelShow(XHPProficiency, b=b, s=1/a, c=c, d=d,
                                         m=0, prior="uniform")

XHPProficiency          <- modelChooseAdd(XHPProficiency, criteria=criteria)
XHPProficiency          <- XHPProficiency[which(XHPProficiency$critLL == TRUE),]
mean(XHPProficiency$T);sd(XHPProficiency$T,na.rm=TRUE);XHPProficiency[1:10,]
meanModels(XHPProficiency, statistic=c("LL","BIC","T","SeT","S","C","D"))
table(XHPProficiency$MODEL)

# Low proficiency students giving correct responses to 20% of the last items
# (more difficult ones)
XLProficiency           <- X
pourcCheat              <- 0.20
nCheat                  <- abs(dim(X)[2]*pourcCheat);
XLProficiency[, (nItems-nCheat+1):nItems] <- rep(1, dim(X)[1]*dim(X)[2]*pourcCheat)
XLProficiency           <- m4plModelShow(XLProficiency, b=b,
                                         s=1/a, c=c, d=d, m=0, prior="uniform")

XLProficiency           <- modelChooseAdd(XLProficiency,
                                         criteria=criteria)

XLProficiency <- XLProficiency[which(XLProficiency$critLL == TRUE),]

```

```
mean(XLProficiency$T);sd(XLProficiency$T,na.rm=TRUE);XLProficiency[1:10,]
meanModels(XLProficiency, statistic=c("LL","BIC","T","SeT","S","C","D"))
table(XLProficiency$MODEL)
```

modelShowClassFunctions

Functions To Manipulate modelShow Class Objects

Description

A set of functions to manipulate modelShow class objects. `is.modelShow` is used to verify if the object correspond to a modelShow class object. `Round.modelShow` is used to control the number of decimals of the report. Finally, `summary.modelShow` produces different summary reports according th the report value.

Usage

```
## S3 method for class 'modelShow'
is(x)

Round(x, digits)

## S3 method for class 'modelShow'
Round(x, digits = 6)

## S3 method for class 'modelShow'
summary(object, ..., report="means",
         statistics=c("LL","BIC","T"),
         criteria="LL", digits=6, tol=0.20, color="grey")
```

Arguments

<code>x</code>	modelShow: modelShow object.
<code>object</code>	modelShow: modelShow object.
<code>digits</code>	numeric: number of report decimal digits.
<code>report</code>	character: summary type to be reported (means, choose, table or add).
<code>statistics</code>	character: a vector of variables for which means of statistics from <code>m4plModelShow</code> will be computed.
<code>criteria</code>	character: criteria used to choose between models (LL, AIC or BIC).
<code>tol</code>	numeric: tolerance around the choose criteria, so that more models can be considered.
<code>color</code>	character: color of the bars if a histogram is choosen for the report.
<code>...</code>	generic: to be able to pass parameters from the generic summary function.

Value

Generic functions for the modelShow class:

is.modelShow logical: is the object of the class modelShow?
 Round.modelShow
 data.frame: return the modelShow object results rounded to digits decimals.

Different reports returned by summary.modelShow

report="means" data.frame: means of the statistics choosen for each models.
 report="choosen"
 list: which model is choosen for each subject.

report="table" table: table of frequencies of each model chhosen.

report="histogram"
 histogram: histogram of frequencies of each model choosen.

report="add" data.frame: the choosen model is added to the essai modelShow object.

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See Also

[m4plModelShow](#)

Examples

```
## GENERATION OF VECTORS OF RESPONSE
# NOTE THE USUAL PARAMETRIZATION OF THE ITEM DISCRIMINATION,
# THE VALUE OF THE PERSONNAL FLUCTUATION FIXED AT 0,
# AND THE VALUE OF THE PERSONNAL PSEUDO-GUESSING FIXED AT 0.30.
# IT COULD BE TYPICAL OF PLAGIARISM BEHAVIOR.
nItems <- 40
a      <- rep(1.702,nItems); b <- seq(-5,5,length=nItems)
c      <- rep(0,nItems); d <- rep(1,nItems)
nSubjects <- 1; rep <- 100
theta  <- seq(-2,-2,length=nSubjects)
S      <- runif(n=nSubjects,min=0.0,max=0.0)
C      <- runif(n=nSubjects,min=0.3,max=0.3)
D      <- runif(n=nSubjects,min=0,max=0)
set.seed(seed = 100)
X      <- ggrm4pl(n=nItems, rep=rep,
                 theta=theta, S=S, C=C, D=D,
                 s=1/a, b=b,c=c,d=d)

## Results for each subjects for each models
essai <- m4plModelShow(X, b=b, s=1/a, c=c, d=d, m=0, prior="uniform")
```

```

## Is essai of class modelShow?
  is.modelShow(essai)

## Rounding to 2 decimals the first 5 results of essai
  Round(essai[1:5,], 2)

## Means for each models rounded to 3 decimals
  summary(essai, report="means", statistics=c("LL", "AIC", "BIC", "T", "SeT"), digits=3)

## Model choosen for each of the first 5 subjects
## and the frequency of these choices with the BIC criteria
  summary(essai[which(essai$ID == (1:5)),], report="choose", criteria="BIC")

## Frequency of the models choosen for all the subjects
## with the LL, AIC and BIC criteria
## Generally, BIC chooses the less models AIC the more.
  summary(essai, report="table", criteria="LL")
  summary(essai, report="table", criteria="AIC")
  summary(essai, report="table", criteria="BIC")

## Frequency of the models choosen for all the subjects
## with the BIC criteria, but with a histogram
  summary(essai, report="histogram", criteria="BIC", color="blue")

## The choosen model is added to the essai modelShow object for all the subjects
## with the LL, AIC and BIC criteria and statistics about theta are computed
## Recall thet rhe generating theta was fixed at -2.00
## The LL criteria seems the best one her according to bias and standard error
  resultLL <- summary(essai, report="add", criteria="LL")
  resultAIC <- summary(essai, report="add", criteria="AIC")
  resultBIC <- summary(essai, report="add", criteria="BIC")
  # LL
  summary(resultLL[which(resultLL$critLL == TRUE),]$T)
  sd(resultLL[which(resultLL$critLL == TRUE),]$T, na.rm=TRUE)
  # AIC
  summary(resultAIC[which(resultAIC$critAIC == TRUE),]$T)
  sd(resultAIC[which(resultAIC$critAIC == TRUE),]$T, na.rm=TRUE)
  # BIC
  summary(resultBIC[which(resultBIC$critBIC == TRUE),]$T)
  sd(resultBIC[which(resultBIC$critBIC == TRUE),]$T, na.rm=TRUE)

```

PersonParametersEstimate

Estimation of the Personal Parameters from the mpl4 Logistic Model

Description

Estimation of the Personal Parameters from the mpl4 Logistic Model.

Usage

```

m4plEstimate(      x , s = 1/1.702, b = 0, c = 0, d = 1, m = 0,
                  model = "T", prior = "uniform")

m4plEstimateMore( x , s = 1/1.702, b = 0, c = 0, d = 1, m = 0,
                  model = "T", prior = "uniform")

m4plPersonParameters(x, s = 1/1.702, b = 0, c = 0, d = 1, m = 0,
                    model = "T", prior = "uniform", more = FALSE)

```

Arguments

x	integer; vector of item responses for only one subject. Cannot be a matrix for the moment.
s	numeric; vector of item fluctuation parameter or the inverse of item discrimination ($s = 1/a$).
b	numeric; vector of item discrimination parameter.
c	numeric; vector of item pseudo-guessing parameter.
d	numeric; vector of item inattention parameter.
m	a priori distribution mean.
model	character; different combinations of personal parameters can be estimated ("T", "S", "C", "D", "SC", "SD", "CD" or "SCD").
prior	character; a priori distribution can be "uniform" (U(m-4, m+4)) or "normal" (N(m, 1)).
more	logical: if TRUE use m4plEstimateMore, if FALSE use m4plEstimate.

Details

The multidimensional 4 persons parameters logistic distribution (cdf) is equal to:

$$P(x_{ij} = 1 | \theta_j, \sigma_j, \chi_j, \delta_j, s_i, b_i, c_i, d_i) = (\chi_j + c_i) + \frac{(d_i - \delta_j) - (\chi_j + c_i)}{1 + e^{\frac{-D_{\alpha_i}(\theta_j - b_i)}{\sqrt{\sigma_j^2 + s_i^2}}}}$$

where the parameters are defined in the section arguments and i and j are respectively the items and the persons indices. The σ_j , χ_j and δ_j parameters are respectively the personal fluctuation, pseudo-guessing and inattention parameters. The multidimensional 4 persons parameters logistic model (M4PL) was described by Raiche, Magis and Blais (2008; Raiche, Magis and Beland, 2009; Raiche, Blais and Magis, 2009).

Value

Function m4plEstimate

m4plEstimate numeric; return a vector of personal parameters estimates.

Function m4plEstimateMore

res numeric; return a vector of personal parameters estimates.
 se numeric; return a vector of standard errors.
 corr numeric; return a correlation matrix between the estimated parameters.
 llikelihood numeric; return a vector of -log likelihood.

Function `m4plPersonParameters` Values returned are from `m4plEstimate` or `m4plEstimateMore` depending on the more condition.

Author(s)

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References

Blais, J.-G., Raiche, G. and Magis, D. (2009). La detection des patrons de reponses problematiques dans le contexte des tests informatises. In Blais, J.-G. (Ed.): *Evaluation des apprentissages et technologies de l'information et de la communication : enjeux, applications et modeles de mesure*. Ste-Foy, Quebec: Presses de l'Universite Laval.

Raiche, G., Magis, D. and Beland, S. (2009). *La correction du resultat d'un etudiant en presence de tentatives de fraudes*. Communication presentee a l'Universite du Quebec a Montreal. Retrieved from <http://www.camri.uqam.ca/camri/camriBase/>

Raiche, G., Magis, D. and Blais, J.-G. (2008). *Multidimensional item response theory models integrating additional inattention, pseudo-guessing, and discrimination person parameters*. Communication at the annual international Psychometric Society meeting, Durham, New Hamshire. Retrieved from <http://www.camri.uqam.ca/camri/camriBase/>

See Also

[grm4pl](#), [ggrm4pl](#), [pggrm4pl](#)

Examples

```
## GENERATION OF VECTORS OF RESPONSE
# NOTE THE USUAL PARAMETRIZATION OF THE ITEM DISCRIMINATION,
# THE VALUE OF THE PERSONNAL FLUCTUATION FIXED AT 0,
# AND THE VALUE OF THE PERSONNAL PSEUDO-GUESSING FIXED AT 0.30.
# IT COULD BE TYPICAL OF PLAGIARISM BEHAVIOR.
nItems <- 40
a      <- rep(1.702,nItems); b <- seq(-5,5,length=nItems)
c      <- rep(0,nItems); d <- rep(1,nItems)
nSubjects <- 1; rep <- 2
theta   <- seq(-1,-1,length=nSubjects)
S      <- runif(n=nSubjects,min=0.0,max=0.0)
C      <- runif(n=nSubjects,min=0.3,max=0.3)
D      <- runif(n=nSubjects,min=0,max=0)
set.seed(seed = 100)
X      <- ggrm4pl(n=nItems, rep=rep,
```

```

theta=theta, S=S, C=C, D=D,
s=1/a, b=b,c=c,d=d)

## Generic function m4plPersonParameters to use
## preferred to the more specific one: m4plEstimate and m4plEstimateMore
# .....
model <- "C"
test1 <- m4plPersonParameters(x=X, b=b, s=1/a, c=c, d=d, m=0, model=model,
                             prior="uniform", more=FALSE)
test2 <- m4plPersonParameters(x=X, b=b, s=1/a, c=c, d=d, m=0, model=model,
                             prior="uniform", more=TRUE)
# .....

## ESTIMATION OF THE PERSONNAL PARAMETERS BY ALL MODELS.
# THE CHOOSEN PRIOR IS UNIFORM WITH m=0.
# .....
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "T",   prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "S",   prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "C",   prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "D",   prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SC",  prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SD",  prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "CD",  prior="uniform")
m4plEstimate(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SCD", prior="uniform")
# .....

## THE SAME ESTIMATION, BUT WITH INFORMATION ABOUT
# THE STANDARD ERROR, THE CORRELATION AND THE LOG LIKELIKOOD
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "T",   prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "S",   prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "C",   prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "D",   prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SC",  prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SD",  prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "CD",  prior="uniform")
m4plEstimateMore(x=X, b=b, s=1/a, c=c, d=d, m=0, model= "SCD", prior="uniform")
# .....

## Same simulation, but with replications
# .....
rep <- 100
set.seed(seed = 100)
X      <- ggrm4pl(n=nItems, rep=rep,
                 theta=theta, S=S, C=C, D=D,
                 s=1/a, b=b,c=c,d=d)

## Function used to extract each parameters of the list return by m4plEstimateMore
extract <- function(x,i) x[[i]]

## Usual IRT model integrating only the parameters theta
apply(      X, 1, m4plEstimate,      b=b, s=1/a, c=c, d=d, m=0, model= "T",
           prior="uniform")
tests <- apply(X, 1, m4plEstimateMore, b=b, s=1/a, c=c, d=d, m=0, model= "T",

```

```

        prior="uniform")
personParameters <- matrix(unlist(lapply(tests,extract,1)),nrow=rep)
personSe         <- matrix(unlist(lapply(tests,extract,2)),nrow=rep)
personCor        <- matrix(unlist(lapply(tests,extract,3)),nrow=rep)
personLL         <- matrix(unlist(lapply(tests,extract,4)),nrow=rep)
results          <- data.frame(Parameter=personParameters, Se=personSe,
                               LL=personLL)
round(c(mean=sapply(results, mean, na.rm=TRUE)),2); round(c(se=sapply(results, sd, na.rm=TRUE)),2)

## Model integrating the parameters theta and C
# Same response patterns for comparison of estimates
t(      apply(X, 1, m4plEstimate,      b=b, s=1/a, c=c, d=d, m=0, model= "C",
             prior="uniform"))
tests <- apply(X, 1, m4plEstimateMore, b=b, s=1/a, c=c, d=d, m=0, model= "C",
             prior="uniform")
personParameters <- t(matrix(unlist(lapply(tests,extract,1)),ncol=rep))
personSe         <- t(matrix(unlist(lapply(tests,extract,2)),ncol=rep))
personLL         <- t(matrix(unlist(lapply(tests,extract,4)),ncol=rep))
results          <- data.frame(Parameter=personParameters, Se=personSe,
                               LL=personLL)
round(c(mean=sapply(results, mean, na.rm=TRUE)),2); round(c(se=sapply(results, sd, na.rm=TRUE)),2)
## Average correlation between the person parameters
nParameters <- length(personParameters[1,])
personCor   <- unlist(lapply(tests,extract,3))
personCor   <- matrix( sapply(data.frame(t(matrix(personCor,ncol=rep))), mean, na.rm=TRUE),
                    ncol=nParameters)

personCor

## Model integrating the parameters theta and C
# Same response patterns for comparison of estimates
t(apply(      X,1, m4plEstimate,      b=b, s=1/a, c=c, d=d, m=0, model= "SCD",
             prior="uniform"))
tests <- apply(X, 1, m4plEstimateMore, b=b, s=1/a, c=c, d=d, m=0, model= "SCD",
             prior="uniform")
personParameters <- t(matrix(unlist(lapply(tests,extract,1)),ncol=rep))
personSe         <- t(matrix(unlist(lapply(tests,extract,2)),ncol=rep))
personLL         <- t(matrix(unlist(lapply(tests,extract,4)),ncol=rep))
results          <- data.frame(Parameter=personParameters, Se=personSe,
                               LL=personLL)
round(c(mean=sapply(results, mean, na.rm=TRUE)),2); round(c(se=sapply(results, sd, na.rm=TRUE)),2)
## Average correlation between the person parameters
nParameters <- length(personParameters[1,])
personCor   <- unlist(lapply(tests,extract,3))
personCor   <- matrix( sapply(data.frame(t(matrix(personCor,ncol=rep))), mean, na.rm=TRUE),
                    ncol=nParameters)

personCor
# .....
```

responses4pl

Simulation of Response Patterns and Computation of the Probability of the Patterns

Description

Simulation of response patterns and computation of the probability of the patterns according to the one, two, three and four parameters logistic item response models.~

Usage

```
gr4pl(N = 10, theta = 0, a = 1, b = 0, c = 0, d = 1)
```

```
ggr4pl(n = 5, rep = 1, theta = 0, a = rep(1, n), b = rep(0, n),
       c = rep(0, n), d = rep(1, n))
```

```
pggr4pl(x = ggr4pl(rep = 1), rep = 1, n = dim(x)[2], N = dim(x)[1],
        theta = rep(0, N), a = rep(1, n), b = rep(0, n), c = rep(0, n),
        d = rep(1, n), log.p=FALSE, TCC = FALSE)
```

Arguments

theta	numeric; vector of proficiency levels (z scores).
x	numeric matrix; response patterns (0 or 1).
rep	numeric; number of replications of the simulation of the response patterns.
n	numeric; number of items.
N	numeric; number of response patterns
a	numeric; item discrimination parameters.
b	numeric; item difficulty parameters.
c	numeric; item pseudo-guessing parameters.
d	numeric; item inattention parameters.
log.p	logical; if TRUE, probabilities p are given as log(p).
TCC	logical; if TRUE generate the TCC figures for each response patterns. Default FALSE.

Details

The function `gr4pl` generates `N` responses to an item according to the `theta` parameter and the items parameters. The function `ggr4pl` will be used to generate `rep` response patterns at `n` items. To compute the probability of the response patterns, according to known person and item parameters, the function `pggr4pl` will be applied.

Value

gr4pl numeric; vector of item responses (0 or 1).
 ggr4pl numeric; data.frame of responses at n items.
 pggr4pl logical; if (TCC ==TRUE) return(list(prob=prob, tcc=tcc)); if (TCC==FALSE)
 return(prob)

Author(s)

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References

Hambleton, R. K. and Swaminathan, H. (1985). *Item response theory - Principles and applications*.
 Boston, Massachuset: Kluwer.

See Also

[grm4pl](#), [ggrm4pl](#), [pggrm4pl](#), [ctt2irt](#), [irt2ctt](#)

Examples

```
## .....
# Generation of reponses (0,1) from r4pl() for N subjects (default value of N= 10)
gr4pl(c = 1)
gr4pl(N = 5, theta = c(-4, 4), c = 0)

# Generation of a 7 responses pattern (0,1) for [rep * length(theta)] subjects
# The subjects number is equal to [rep * length(theta)]
# a,b,c et d are item parameters vectors
nitems <- 7
N <- 10
a <- rep(1, nitems)
b <- rnorm(nitems)
c <- rep(0, nitems)
d <- rep(1, nitems)
theta <- seq(-4,4,length=5)
x <- ggr4pl(n = nitems, rep = N, theta = theta, a = a, b = b, c = c, d = d)
x

## Probability of a 10 responses pattern and test caracteristic curve (TCC)
nitems <- 10
a <- rep(1,nitems)
b <- seq(-4,4,length=nitems)
c <- rep(0,nitems)
d <- rep(1,nitems)
N <- 3
theta <- seq(-1,1,length=12)
# Generation of the response patterns
```

```

x      <- ggr4pl(n = nitems, rep = N, theta = theta, a = a, b = b, c = c, d = d)
x
# Without TCC
res    <- pggr4pl(x=x, rep=N, theta=theta,a=a,c=c,d=d,TCC=FALSE); res
# With TCC for each response pattern
res    <- pggr4pl(x=x, rep=N, theta=theta,a=a,c=c,d=d,TCC=TRUE); res
## .....

```

responsesm4pl

Simulation of Response Patterns and Computation of the Probability of the Patterns from m4pl

Description

Simulation of response patterns and computation of the probability of the patterns according to the multidimensional one, two, three and four person parameters logistic item response models.

Usage

```

grm4pl(N = 10, theta = 0, S = 0, C = 0, D = 0, s = 1/1.702, b = 0, c = 0, d = 1)

```

```

ggrm4pl(n=5,rep=1,theta=0,S=rep(0,length(theta)),C=rep(0,length(theta)),
        D=rep(0,length(theta)),s=rep(1/1.702,n),b=rep(0,n),c=rep(0,n),
        d=rep(1, n))

```

```

pggrm4pl(x=ggrm4pl(rep=1),rep=1,n=dim(x)[2],N=dim(x)[1],theta=rep(0,N),
        S=0,C=0,D=0,s=rep(1/1.702,n),b=rep(0,n),c=rep(0,n),d=rep(1,n),
        log.p=FALSE, TCC=FALSE)

```

Arguments

x	integer matrix; response patterns (0 or 1).
rep	numeric; number of replications of the simulation of the response patterns.
n	numeric; number of items.
N	numeric; number of response patterns
theta	numeric; vector of proficiency levels (z scores).
S	numeric; person fluctuation parameter.
C	numeric; person pseudo-guessing parameter.
D	numeric; person inattention parameter.
s	numeric; item fluctuation parameters.
b	numeric; item difficulty parameters.
c	numeric; item pseudo-guessing parameters.

d	numeric; item inattention parameters.
log.p	logical; if TRUE, probabilities p are given as log(p).
TCC	logical; if TRUE generate the TCC figures for each response patterns. Default FALSE.

Details

The function `grm4pl` generates N responses to an item according to the person parameters and the items parameters. The function `ggrm4pl` will be used to generate rep response patterns at n items. To compute the probability of the response patterns, according to known person and item parameters, the function `pggrm4pl` will be applied.

Value

<code>grm4pl</code>	integer; vector of item responses (0 or 1).
<code>ggrm4pl</code>	integer data.frame; responses for n items.
<code>pggrm4pl</code>	graphic; if (TCC ==TRUE) return(list(prob=prob, tcc=tcc)). If (TCC==FALSE) return(prob).

Author(s)

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See Also

[gr4pl](#), [ggr4pl](#), [pggr4pl](#), [ctt2irt](#), [irt2ctt](#)

Examples

```
## .....
# Generation of response patterns (0,1) from r4pl() for N subjects (default value
# of N = 10)

# Generation of a response (0,1) from rm4pl for N subjects
grm4pl(theta=0)
grm4pl(N=5, theta=c(-4,4), c=0)

# Generation of n m4pl response patterns (0,1) for [rep * length(theta)] subjects
# The subject number ia equal to [rep * length(theta)]
# a,b,c et d are item parameters vectors
nitems <- n <- 7; N <- 1
s <- rep(0,nitems); b <- seq(-4,4,length=nitems); c <- rep(0,nitems)
d <- rep(1,nitems)
theta <- seq(-4,4,length=5)
x <- ggrrm4pl(n=nitems, rep=N, theta=theta,s=s,b=b,c=c,d=d)
x

# TO BE REWORKED - Probability of a response pattern and test characteristic curve
# (TCC)
nItems <- n <- 7; N <- 1
s <- rep(0,nItems); b <- seq(-4,4,length=nItems)
c <- rep(0,nItems); d <- rep(1,nItems)
theta <- seq(-4,4,length=5); S <- rep(1/1.702,length(theta));
C <- rep(0.3,length(theta)); D <- rep(0,length(theta))
x <- ggrrm4pl(n=nItems, rep=N, theta=theta, S=S, C=C, D=D, s=s, b=b, c=c, d=d)
x
res <- pgrrm4pl(x=x, rep=N, theta=theta, S=1/1.702, C=0.3, D=0, s=s, c=c, d=d,
TCC=TRUE)

res
res <- pgrrm4pl(x=x, rep=N, theta=rep(2,length(theta)), S=1/1.702, C=0, D=0,
s=s, c=c, d=d, TCC=FALSE)

res
pgrrm4pl(theta=3)
pgrrm4pl(n=10, theta=seq(-4,4,length=5), x=ggrrm4pl(rep=1), TCC=TRUE)
## .....
```

utilities

Utility Functions

Description

Some functions to help in the generation of binary data or to interpret m4pl models results.

`rmultinomial` is used to draw `n` values from a `x` vector of values according to a multinomial probability distribution. `rmultinomial` is different from the `stats::rmultinom` function in that it return only the value of the selected draw and not a binary vector corresponding tho the position of the draw

propCorrect computes the expected proportion of correct responses to a test according to the item and person parameters of a m4p1 models.

Usage

```
rmultinomial(x, n = 100, prob = rep(1, length(x))/length(x))
```

```
propCorrect(theta, S, C, D, s, b, c, d)
```

Arguments

x	numeric: vector of values to draw from.
n	numeric: number of draws.
prob	numeric: probability assigned to each value of the x vector. Default to equiprobability.
theta	numeric; vector of person proficiency (θ) levels scaled on a normal z score.
S	numeric: positive vector of personal fluctuation parameters (σ).
C	numeric: positive vector of personal pseudo-guessing parameters (χ , a probability between 0 and 1).
D	numeric: positive vector of personal inattention parameters (δ , a probability between 0 and 1).
s	numeric: positive vector of item fluctuation parameters.
b	numeric: vector of item difficulty parameters.
c	numeric: positive vector of item pseudo-guessing parameters (a probability between 0 and 1).
d	numeric: positive vector of item inattention parameters (a probability between 0 and 1).

Value

propCorrect

numeric: return n draws from a multinomial distribution.

rmultinomial

numeric: return the expected proportion of correct responses to a test.

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See Also

[Multinom](#)

Examples

```

## Comparison of the results from the multinomial and multinom functions
x <- c(1,4,9)
# Values draws
rmultinomial(x=x, n=10)
# Binary vectors draws
rmultinom(n=10, size = 1, prob=rep(1,length(x))/length(x))

## Computation of the expected proportion of correct responses varying values
# of theta (-3 to 3) and of pseudo-guessing (C = 0.0 to 0.6) person parameters
nItems <- 40
a <- rep(1.702,nItems); b <- seq(-3,3,length=nItems)
c <- rep(0,nItems); d <- rep(1,nItems)
theta <- seq(-3.0, 3.0, by=1.0)
C <- seq( 0.0, 1.0, by=0.1)
D <- S <- 0

results <- matrix(NA, ncol=length(C), nrow=length(theta))
colnames(results) <- C; rownames(results) <- theta
for (i in (1:length(theta))) {
  results[i,] <- propCorrect(theta = theta[i], S = 0, C = C, D = 0,
                           s = 1/a, b = b, c = c, d = d)
}
round(results, 2)

## Computation of the expected proportion of correct responses varying values
# of theta (-3 to 3) and of pseudo-guessing (C = 0.0 to 0.6) person parameters
# if we choose the correct modelisation integrating the C pseudo-guessing parameter
# and if we choose according to a model selection by LL criteria
nItems <- 40
a <- rep(1.702,nItems); b <- seq(-3,3,length=nItems)
c <- rep(0,nItems); d <- rep(1,nItems)
nSubjects <- 300
theta <- rmultinomial(c(-1), nSubjects)
S <- rmultinomial(c(0), nSubjects)
C <- rmultinomial(seq(0,0.9,by=0.1), nSubjects)
D <- rmultinomial(c(0), nSubjects)
set.seed(seed = 100)
X <- ggrm4pl(n=nItems, rep=1,
            theta=theta, S=S, C=C, D=D,
            s=1/a, b=b,c=c,d=d)
# Results for each subjects for each models
essai <- m4plModelShow(X, b=b, s=1/a, c=c, d=d, m=0, prior="uniform")
total <- rowSums(X)
pourcent <- total/nItems * 100
pCorrect <- numeric(dim(essai)[1])
for ( i in (1:dim(essai)[1]))
  pCorrect[i] <- propCorrect(essai$T[i],0,0,0,s=1/a,b=b,c=c,d=d)
resultLL <- summary(essai, report="add", criteria="LL")
resultLL <- data.frame(resultLL, theta=theta, TS=S, TC=C, errorT=resultLL$T - theta,
                      total=total, pourcent=pourcent, tpcorrect=pCorrect)
# If the only theta model is badly chosen

```

```

results <- resultLL[which(resultLL$MODEL == "T" ),]
byStats <- "TC"; ofStats <- "tpcorrect"
MeansByThetaT <- cbind(
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats]) ),
    mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats])), sd, na.rm=TRUE),
  aggregate(results["SeT"], by=list(Theta=factor(results[,byStats])), mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(theta=factor(results[,byStats])), length)
)[,-c(3,5,7)]
names(MeansByThetaT) <- c("C", "pCorrect", "seE", "SeT", "n")
MeansByThetaT[,-c(1,4,5)] <- round(MeansByThetaT[,-c(1,4,5)], 2)
MeansByThetaT[,-c(4,5)]
# Only for the TC model
results <- resultLL[which(resultLL$MODEL == "TC" ),]
byStats <- "TC"; ofStats <- "tpcorrect"
MeansByThetaC <- cbind(
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats]) ),
    mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats])), sd, na.rm=TRUE),
  aggregate(results["SeT"], by=list(Theta=factor(results[,byStats])), mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(theta=factor(results[,byStats])), length)
)[,-c(3,5,7)]
names(MeansByThetaC) <- c("C", "pCorrect", "seE", "SeT", "n")
MeansByThetaC[,-c(1,4,5)] <- round(MeansByThetaC[,-c(1,4,5)], 2)
MeansByThetaC[,-c(4,5)]
# For the model choosen according to the LL criteria
results <- resultLL[which(resultLL$critLL == TRUE),]
byStats <- "TC"; ofStats <- "tpcorrect"
MeansByThetaLL <- cbind(
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats]) ),
    mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(Theta=factor(results[,byStats])), sd, na.rm=TRUE),
  aggregate(results["SeT"], by=list(Theta=factor(results[,byStats])), mean, na.rm=TRUE),
  aggregate(results[ofStats], by=list(theta=factor(results[,byStats])), length)
)[,-c(3,5,7)]
names(MeansByThetaLL) <- c("C", "pCorrect", "seE", "SeT", "n")
MeansByThetaLL[,-c(1,4,5)] <- round(MeansByThetaLL[,-c(1,4,5)], 2)
MeansByThetaLL[,-c(4,5)]
# Grapical comparison of the estimation of the % of correct responses
# by means of the 3 preceeding models
plot(MeansByThetaT$pCorrect ~ levels(MeansByThetaT$C), type="l", lty=1,
  xlab="Pseudo-Guessing", ylab="% of Correct Responses")
lines(MeansByThetaC$pCorrect ~ levels(MeansByThetaC$C), type="l", lty=2)
lines(MeansByThetaLL$pCorrect ~ levels(MeansByThetaLL$C), type="l", lty=3)
text(x=0.60, y=0.80, "Without correction", cex=0.8)
text(x=0.50, y=0.38, "Without Knowledge of the Correct Model", cex=0.8)
text(x=0.65, y=0.50, "With Knowledge of the Correct Model", cex=0.8)

```

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