Package ‘difNLR’

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Type Package

Title DIF and DDF Detection by Non-Linear Regression Models

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Author Adela Hladka [aut, cre],
Patricia Martinkova [aut],
Karel Zvara [ctb]

Maintainer Adela Hladka <hladka@cs.cas.cz>

Depends R (>= 4.0.0)

Imports calculus, ggplot2 (>= 3.4.0), msm, nnet, plyr, stats, VGAM

Suggests ShinyItemAnalysis, testthat (>= 3.0.0)

Description Detection of differential item functioning (DIF) among dichotomously scored items and differential distractor functioning (DDF) among unscored items with non-linear regression procedures based on generalized logistic regression models (Hladka & Martinkova, 2020, <doi:10.32614/RJ-2020-014>).

License GPL-3

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BugReports https://github.com/adelahladka/difNLR/issues

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Contents

`difNLR-package` *DIF and DDF Detection by Non-Linear Regression Models.*

Description

The difNLR package provides methods for detecting differential item functioning (DIF) using non-linear regression models. Both uniform and non-uniform DIF effects can be detected when considering a single focal group. Additionally, the method allows for testing differences in guessing or inattention parameters between the reference and focal group. DIF detection is performed using either a likelihood-ratio test, an F-test, or Wald's test of a submodel. The software offers a variety of algorithms for estimating item parameters.

Furthermore, the difNLR package includes methods for detecting differential distractor functioning (DDF) using multinomial log-linear regression model. It also introduces DIF detection approaches for ordinal data via adjacent category logit and cumulative logit regression models.

Details

Package: difNLR
Type: Package
Version: 1.5.1-1
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Depends: R (>= 4.0.0)
Imports: calculus, ggplot2 (>= 3.4.0), msm, nnet, plyr, stats, VGAM
Suggests: ShinyItemAnalysis, testthat (>= 3.0.0)
License: GPL-3
BugReports: https://github.com/adelahladka/difNLR/issues
Encoding: UTF-8

Functions

- ddfMLR
- difNLR
- difORD
- estimNLR
- formulaNLR
- MLR
- NLR
- ORD
- startNLR

Datasets

- GMAT
- GMAT2
- MSATB

Note

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Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

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Swaminathan, H. & Rogers, H. J. (1990). Detecting differential item functioning using logistic regression procedures. Journal of Educational Measurement, 27(4), 361–370, doi:10.1111/j.1745-3984.1990.tb00754.x

Vlckova, K. (2014). Test and item fairness. Master's thesis. Faculty of Mathematics and Physics, Charles University.

See Also

Useful links:

- Report bugs at `https://github.com/adelahladka/difNLR/issues`

`coef.ddfMLR` *Extract model coefficients from an object of* `"ddfMLR"` *class.*

Description

S3 method for extracting estimated model coefficients from an object of `"ddfMLR"` class.

Usage

```
## S3 method for class 'ddfMLR'
coef(object, SE = FALSE, simplify = FALSE, IRTpars = TRUE, CI = 0.95, ...)
```

Arguments

`object`	an object of `"ddfMLR"` class.
`SE`	logical: should the standard errors of estimated parameters be also returned? (default is `FALSE`).
`simplify`	logical: should the estimated parameters be simplified to a matrix? (default is `FALSE`).
`IRTpars`	logical: should the estimated parameters be returned in IRT parameterization? (default is `TRUE`).
`CI`	numeric: level of confidence interval for parameters, default is `0.95` for 95% confidence interval.
`...`	other generic parameters for `coef()` function.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

`ddfMLR` for DDF detection among nominal data.
`coef` for generic function extracting model coefficients.

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
(x <- ddfMLR(Data, group, focal.name = 1, key))

# estimated parameters
coef(x)
# includes standard errors
coef(x, SE = TRUE)
# includes standard errors and simplifies to matrix
coef(x, SE = TRUE, simplify = TRUE)
# intercept-slope parameterization
```

```
coef(x, IRTpars = FALSE)
# intercept-slope parameterization, simplifies to matrix, turn off confidence intervals
coef(x, IRTpars = FALSE, simplify = TRUE, CI = 0)

## End(Not run)
```

`coef.difNLR` *Extract item parameter estimates from an object of the* `"difNLR"` *class.*

Description

S3 method for extracting the item parameter estimates from an object of the `"difNLR"` class.

Usage

```
## S3 method for class 'difNLR'
coef(
  object,
  item = "all",
  SE = FALSE,
  simplify = FALSE,
  IRTpars = TRUE,
  CI = 0.95,
  ...
)
```

Arguments

`object`	an object of the `"difNLR"` class.
`item`	numeric or character: either character `"all"` to apply for all converged items (default), or a vector of item names (column names of the `Data`), or item identifiers (integers specifying the column number).
`SE`	logical: should the standard errors of the estimated item parameters be also returned? (the default is `FALSE`).
`simplify`	logical: should the estimated item parameters be simplified to a matrix? (the default is `FALSE`).
`IRTpars`	logical: should the estimated item parameters be returned in he IRT parameterization? (the default is `TRUE`).
`CI`	numeric: a significance level for confidence intervals (CIs) of item parameter estimates (the default is `0.95` for 95% CI). With 0 value, no CIs are displayed.
`...`	other generic parameters for the `coef()` method.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`difNLR` for DIF detection among binary data using the generalized logistic regression model.
`coef` for a generic function for extracting parameter estimates.

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))

# estimated parameters
coef(x)
# includes standard errors
coef(x, SE = TRUE)
# includes standard errors and simplifies to matrix
coef(x, SE = TRUE, simplify = TRUE)
# intercept-slope parameterization
coef(x, IRTpars = FALSE)
# intercept-slope parameterization, simplifies to matrix, turn off confidence intervals
coef(x, IRTpars = FALSE, simplify = TRUE, CI = 0)
# for DIF items only
```

```
coef(x, item = x$DIFitems, IRTpars = FALSE, simplify = TRUE, CI = 0)

## End(Not run)
```

`coef.difORD` *Extract model coefficients from an object of* `"difORD"` *class.*

Description

S3 method for extracting estimated model coefficients from an object of `"difORD"` class.

Usage

```
## S3 method for class 'difORD'
coef(object, SE = FALSE, simplify = FALSE, IRTpars = TRUE, CI = 0.95, ...)
```

Arguments

`object`	an object of `"difORD"` class.
`SE`	logical: should the standard errors of estimated parameters be also returned? (default is `FALSE`).
`simplify`	logical: should the estimated parameters be simplified to a matrix? (default is `FALSE`).
`IRTpars`	logical: should the estimated parameters be returned in IRT parameterization? (default is `TRUE`).
`CI`	numeric: level of confidence interval for parameters, default is `0.95` for 95% confidence interval.
`...`	other generic parameters for `coef()` function.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

`difORD` for DIF detection among ordinal data.
`coef` for generic function extracting model coefficients.

Examples

```
## Not run:
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects with adjacent category logit model
(x <- difORD(Data, group, focal.name = 1, model = "adjacent"))

# estimated parameters
coef(x)
# includes standard errors
coef(x, SE = TRUE)
# includes standard errors and simplifies to matrix
coef(x, SE = TRUE, simplify = TRUE)
# intercept-slope parameterization
coef(x, IRTpars = FALSE)
# intercept-slope parameterization, simplifies to matrix, turn off confidence intervals
coef(x, IRTpars = FALSE, simplify = TRUE, CI = 0)

## End(Not run)
```

---

ddfMLR *DDF detection for nominal data.*

Description

Performs DDF detection procedure for nominal data based on multinomial log-linear regression model and likelihood ratio test of a submodel.

Usage

```
ddfMLR(Data, group, focal.name, key, type = "both", match = "zscore", anchor = NULL,
       purify = FALSE, nrIter = 10, p.adjust.method = "none",
       alpha = 0.05, parametrization)
```

Arguments

`Data`	data.frame or matrix: dataset which rows represent unscored examinee answers (nominal) and columns correspond to the items. In addition, `Data` can hold the vector of group membership.
`group`	numeric or character: a dichotomous vector of the same length as `nrow(Data)` or a column identifier of `Data`.
`focal.name`	numeric or character: indicates the level of `group` which corresponds to focal group.
`key`	character: the answer key. Each element corresponds to the correct answer of one item.

type	character: type of DDF to be tested. Either "both" for uniform and non-uniform DDF (i.e., difference in parameters "a" and "b") (default), or "udif" for uniform DDF only (i.e., difference in difficulty parameter "b"), or "nudif" for non-uniform DDF only (i.e., difference in discrimination parameter "a"). Can be specified as a single value (for all items) or as an item-specific vector.
match	numeric or character: matching criterion to be used as an estimate of trait. Can be either "zscore" (default, standardized total score), "score" (total test score), or vector of the same length as number of observations in Data.
anchor	numeric or character: specification of DDF free items. Either NULL (default), or a vector of item names (column names of Data), or item identifiers (integers specifying the column number) determining which items are currently considered as anchor (DDF free) items. Argument is ignored if match is not "zscore" or "score".
purify	logical: should the item purification be applied? (default is FALSE).
nrIter	numeric: the maximal number of iterations in the item purification (default is 10).
p.adjust.method	character: method for multiple comparison correction. Possible values are "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", "fdr", and "none" (default). For more details see p.adjust.
alpha	numeric: significance level (default is 0.05).
parametrization	deprecated. Use coef.ddfMLR for different parameterizations.

Details

Performs DDF detection procedure for nominal data based on multinomial log-linear regression model and likelihood ratio test of submodel. Probability of selection the k-th category (distractor) is

$$P(y = k) = exp((a_k + a_k Dif * g) * (x - b_k - b_k Dif * g)))/(1 + \sum exp((a_l + a_l Dif * g) * (x - b_l - b_l Dif * g))),$$

where x is by default standardized total score (also called Z-score) and g is a group membership. Parameters a_k and b_k are discrimination and difficulty for the k-th category. Terms $a_k Dif$ and $b_k Dif$ then represent differences between two groups (reference and focal) in relevant parameters. Probability of correct answer (specified in argument key) is

$$P(y = k) = 1/(1 + \sum exp((a_l + a_l Dif * g) * (x - b_l - b_l Dif * g))).$$

Parameters are estimated via neural networks. For more details see multinom.

Missing values are allowed but discarded for item estimation. They must be coded as NA for both, Data and group arguments.

Value

The ddfMLR() function returns an object of class "ddfMLR". The output including values of the test statistics, p-values, and items marked as DDF is displayed by the print() method.

A list of class "ddfMLR" with the following arguments:

`Sval` the values of likelihood ratio test statistics.

`mlrPAR` the estimates of final model.

`mlrSE` standard errors of the estimates of final model.

`parM0` the estimates of null model.

`parM1` the estimates of alternative model.

`llM0` log-likelihood of null model.

`llM1` log-likelihood of alternative model.

`AIC0` AIC of null model.

`AIC1` AIC of alternative model.

`BIC0` BIC of null model.

`BIC1` BIC of alternative model.

`DDFitems` either the column identifiers of the items which were detected as DDF, or `"No DDF item detected"` in case no item was detected as DDF.

`type` character: type of DDF that was tested.

`purification` `purify` value.

`nrPur` number of iterations in item purification process. Returned only if `purify` is `TRUE`.

`ddfPur` a binary matrix with one row per iteration of item purification and one column per item. `"1"` in i-th row and j-th column means that j-th item was identified as DDF in i-th iteration. Returned only if `purify` is `TRUE`.

`conv.puri` logical indicating whether item purification process converged before the maximal number `nrIter` of iterations. Returned only if `purify` is `TRUE`.

`p.adjust.method` character: method for multiple comparison correction which was applied.

`pval` the p-values by likelihood ratio test.

`adj.pval` the adjusted p-values by likelihood ratio test using `p.adjust.method`.

`df` the degress of freedom of likelihood ratio test.

`alpha` numeric: significance level.

`Data` the data matrix.

`group` the vector of group membership.

`group.names` levels of grouping variable.

`key` key of correct answers.

`match` matching criterion.

For an object of class `"ddfMLR"` several methods are available (e.g. `methods(class = "ddfMLR")`).

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

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Hladka, A. (2021). Statistical models for detection of differential item functioning. Dissertation thesis. Faculty of Mathematics and Physics, Charles University.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

plot.ddfMLR for graphical representation of item characteristic curves.
coef.ddfMLR for extraction of item parameters with their standard errors.
logLik.ddfMLR, AIC.ddfMLR, BIC.ddfMLR for extraction of log-likelihood and information criteria.

p.adjust for multiple comparison corrections.
multinom for estimation function using neural networks.

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
(x <- ddfMLR(Data, group, focal.name = 1, key))

# graphical devices
plot(x, item = "Item1", group.names = c("Group 1", "Group 2"))
plot(x, item = x$DDFitems)
plot(x, item = 1)

# AIC, BIC, log-likelihood
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

# estimated parameters
coef(x)
coef(x, SE = TRUE)
coef(x, SE = TRUE, simplify = TRUE)

# testing both DDF effects with Benjamini-Hochberg adjustment method
```

```
ddfMLR(Data, group, focal.name = 1, key, p.adjust.method = "BH")

# testing both DDF effects with item purification
ddfMLR(Data, group, focal.name = 1, key, purify = TRUE)

# testing uniform DDF effects
ddfMLR(Data, group, focal.name = 1, key, type = "udif")
# testing non-uniform DDF effects
ddfMLR(Data, group, focal.name = 1, key, type = "nudif")

# testing both DDF effects with total score as matching criterion
ddfMLR(Data, group, focal.name = 1, key, match = "score")

## End(Not run)
```

`difNLR` *DIF detection using non-linear regression method.*

Description

Performs DIF detection procedure in dichotomous data based on non-linear regression model (generalized logistic regression) and either likelihood-ratio test, F-test, or Wald's test of a submodel.

Usage

```
difNLR(Data, group, focal.name, model, constraints, type = "all",
       method = "nls", match = "zscore", anchor = NULL, purify = FALSE,
       nrIter = 10, test = "LR", alpha = 0.05, p.adjust.method = "none", start,
       initboot = TRUE, nrBo = 20, sandwich = FALSE)
```

Arguments

`Data`	data.frame or matrix: dataset in which rows represent scored examinee answers (`"1"` correct, `"0"` incorrect) and columns correspond to the items. In addition, `Data` can hold the vector of group membership.
`group`	numeric or character: a binary vector of the same length as `nrow(Data)` or a column identifier in the `Data`.
`focal.name`	numeric or character: indicates the level of the `group` corresponding to the focal group.
`model`	character: generalized logistic regression model to be fitted. See **Details**.
`constraints`	character: which parameters should be the same for both groups. Possible values are any combinations of parameters `"a"`, `"b"`, `"c"`, and `"d"`. See **Details**.
`type`	character: type of DIF to be tested. Possible values are `"all"` for detecting differences in any parameters (default), `"udif"` for uniform DIF only (i.e., difference in difficulty parameter `"b"`), `"nudif"` for non-uniform DIF only (i.e., difference in discrimination parameter `"a"`), `"both"` for uniform and non-uniform

DIF (i.e., difference in parameters "a" and "b"), or a combination of parameters "a", "b", "c", and "d". Can be specified as a single value (for all items) or as an item-specific vector.

method — character: an estimation method to be applied. The options are "nls" for non-linear least squares (default), "mle" for the maximum likelihood method using the "L-BFGS-B" algorithm with constraints, "em" for the maximum likelihood estimation with the EM algorithm, "plf" for the maximum likelihood estimation with the algorithm based on parametric link function, and "irls" for the maximum likelihood estimation with the iteratively reweighted least squares algorithm (available for the "2PL" model only). See **Details**.

match — character or numeric: matching criterion to be used as an estimate of the trait. It can be either "zscore" (default, standardized total score), "score" (total test score), or a numeric vector of the same length as a number of observations in the Data.

anchor — character or numeric: specification of DIF free items. Either NULL (default), or a vector of item identifiers (integers specifying the column number) specifying which items are currently considered as anchor (DIF free) items. Argument is ignored if the match is not "zscore" or "score".

purify — logical: should the item purification be applied? (the default is FALSE).

nrIter — numeric: the maximal number of iterations in the item purification (the default is 10).

test — character: a statistical test to be performed for DIF detection. Can be either "LR" for the likelihood ratio test of a submodel (default), "W" for the Wald's test, or "F" for the F-test of a submodel.

alpha — numeric: a significance level (the default is 0.05).

p.adjust.method — character: a method for a multiple comparison correction. Possible values are "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", "fdr", and "none" (default). For more details see p.adjust.

start — numeric: initial values for the estimation of item parameters. If not specified, starting values are calculated with the startNLR function. Otherwise, a list with as many elements as a number of items. Each element is a named numeric vector representing initial values for estimation of item parameters. Specifically, parameters "a", "b", "c", and "d" are initial values for discrimination, difficulty, guessing, and inattention for the reference group. Parameters "aDif", "bDif", "cDif", and "dDif" are then differences in these parameters between the reference and focal groups. For the method = "irls", default initial values from the glm function are used.

initboot — logical: in the case of convergence issues, should starting values be re-calculated based on bootstrapped samples? (the default is TRUE; newly calculated initial values are applied only to items/models with convergence issues).

nrBo — numeric: the maximal number of iterations for the calculation of starting values using bootstrapped samples (the default is 20).

sandwich — logical: should the sandwich estimator be applied for computation of the covariance matrix of item parameters when using method = "nls"? (the default is FALSE).

Details

DIF detection procedure based on non-linear regression is the extension of the logistic regression procedure (Swaminathan & Rogers, 1990) accounting for possible guessing and/or inattention when responding (Drabinova & Martinkova, 2017; Hladka & Martinkova, 2020).

The unconstrained form of the 4PL generalized logistic regression model for probability of correct answer (i.e., $Y_{pi} = 1$) using IRT parameterization is

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR}\cdot G_p + c_{iF}\cdot(1-G_p)) + (d_{iR}\cdot G_p + d_{iF}\cdot(1-G_p) - c_{iR}\cdot G_p - c_{iF}\cdot(1-G_p))/(1+\exp(-(a_i + a_{i\mathrm{DIF}}\cdot G_p)\cdot$$

where X_p is the matching criterion (e.g., standardized total score) and G_p is a group membership variable for respondent p. Parameters a_i, b_i, c_{iR}, and d_{iR} are discrimination, difficulty, guessing, and inattention for the reference group for item i. Terms $a_{i\mathrm{DIF}}$ and $b_{i\mathrm{DIF}}$ then represent differences between the focal and reference groups in discrimination and difficulty for item i. Terms c_{iF}, and d_{iF} are guessing and inattention parameters for the focal group for item i. In the case that there is no assumed difference between the reference and focal group in the guessing or inattention parameters, the terms c_i and d_i are used.

Alternatively, intercept-slope parameterization may be applied:

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR}\cdot G_p + c_{iF}\cdot(1-G_p)) + (d_{iR}\cdot G_p + d_{iF}\cdot(1-G_p) - c_{iR}\cdot G_p - c_{iF}\cdot(1-G_p))/(1+\exp(-(\beta_{i0} + \beta_{i1}\cdot X_p +$$

where parameters $\beta_{i0}, \beta_{i1}, \beta_{i2}, \beta_{i3}$ are intercept, effect of the matching criterion, effect of the group membership, and their mutual interaction, respectively.

The `model` and `constraints` arguments can further constrain the 4PL model. The arguments `model` and `constraints` can also be combined. Both arguments can be specified as a single value (for all items) or as an item-specific vector (where each element corresponds to one item).

The `model` argument offers several predefined models. The options are as follows: `Rasch` for 1PL model with discrimination parameter fixed on value 1 for both groups, `1PL` for 1PL model with discrimination parameter set the same for both groups, `2PL` for logistic regression model, `3PLcg` for 3PL model with fixed guessing for both groups, `3PLdg` for 3PL model with fixed inattention for both groups, `3PLc` (alternatively also `3PL`) for 3PL regression model with guessing parameter, `3PLd` for 3PL model with inattention parameter, `4PLcgdg` for 4PL model with fixed guessing and inattention parameter for both groups, `4PLcgd` (alternatively also `4PLd`) for 4PL model with fixed guessing for both groups, `4PLcdg` (alternatively also `4PLc`) for 4PL model with fixed inattention for both groups, or `4PL` for 4PL model.

The underlying generalized logistic regression model can be further specified in more detail with the `constraints` argument which specifies what parameters should be fixed for both groups. For example, a choice `"ad"` means that discrimination (parameter `"a"`) and inattention (parameter `"d"`) are fixed (and estimated for) both groups and other parameters (`"b"` and `"c"`) are not. The `NA` value for `constraints` means no constraints.

Missing values are allowed but discarded for an item estimation. They must be coded as `NA` for both, the `Data` and `group` arguments.

The function uses intercept-slope parameterization for the estimation via the `estimNLR` function. Item parameters are then re-calculated into the IRT parameterization using the delta method.

The function offers either the non-linear least squares estimation via the `nls` function (Drabinova & Martinkova, 2017; Hladka & Martinkova, 2020), the maximum likelihood method with the `"L-BFGS-B"` algorithm with constraints via the `optim` function (Hladka & Martinkova, 2020), the maximum likelihood method with the EM algorithm (Hladka, Martinkova, & Brabec, 2024), the maximum likelihood method with the algorithm based on parametric link function (PLF, the default option; Hladka, Martinkova, & Brabec, 2024), or the maximum likelihood method with the iteratively reweighted least squares algorithm via the `glm` function.

Value

The `difNLR()` function returns an object of class `"difNLR"`. The output, including values of the test statistics, p-values, and items detected as function differently, is displayed by the `print()` method.

Object of class `"difNLR"` is a list with the following components:

`Sval` the values of the `test` statistics.

`nlrPAR` the item parameter estimates of the final model.

`nlrSE` the standard errors of the item parameter estimates of the final model.

`parM0` the item parameter estimates of the null (smaller) model.

`seM0` the standard errors of item parameter estimates of the null (smaller) model.

`covM0` the covariance matrices of the item parameter estimates of the null (smaller) model.

`llM0` the log-likelihood values of the null (smaller) model.

`parM1` the item parameter estimates of the alternative (larger) model.

`seM1` the standard errors of the item parameter estimates of the alternative (larger) model.

`covM1` the covariance matrices of the item parameter estimates of alternative (larger) model.

`llM1` the log-likelihood values of the alternative (larger) model.

`DIFitems` either the column identifiers of the items which were detected as DIF, or `"No DIF item detected"` in the case no item was detected as function differently.

`model` fitted model.

`constraints` constraints for the `model`.

`type` character: type of DIF that was tested. If a combination of the item parameters was specified, the value is `"other"`.

`types` character: the parameters (specified by user, `type` has value `"other"`) which were tested for difference.

`p.adjust.method` character: a method for the multiple comparison correction which was applied.

`pval` the p-values by the `test`.

`adjusted.pval` adjusted p-values by the `p.adjust.method`.

`df` the degrees of freedom of the `test`.

`test` used test.

`purification` `purify` value.

`nrPur` number of iterations in item purification process. Returned only if `purify` is `TRUE`.

`difPur` a binary matrix with one row per iteration of item purification and one column per item. `"1"` in i-th row and j-th column means that j-th item was identified as DIF in i-th iteration. Returned only if `purify` is `TRUE`.

`conv.puri` logical: indicating whether item purification process converged before the maximal number `nrIter` of iterations. Returned only if `purify` is `TRUE`.

`method` used estimation method.

`conv.fail` numeric: number of convergence issues.

`conv.fail.which` the identifiers of the items which did not converge.

`alpha` numeric: significance level.

`Data` the data matrix.

`group` the vector of group membership.

`group.names` names of groups.

`match` matching criterion.

Several methods are available for an object of the `"difNLR"` class (e.g., `methods(class = "difNLR")`).

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

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See Also

plot.difNLR for a graphical representation of item characteristic curves and DIF statistics.
coef.difNLR for an extraction of item parameters with their standard errors in various parameterizations.
predict.difNLR for prediction.
fitted.difNLR and residuals.difNLR for an extraction of fitted values and residuals.
logLik.difNLR, AIC.difNLR, BIC.difNLR for an extraction of log-likelihood values and information criteria.

p.adjust for multiple comparison corrections.
nls for a nonlinear least squares estimation.
startNLR for a calculation of initial values of fitting algorithms in difNLR().

Examples

```
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))
## Not run:
# graphical devices
plot(x, item = x$DIFitems)
plot(x, item = "Item1")
plot(x, item = 1, group.names = c("Group 1", "Group 2"))
plot(x, plot.type = "stat")

# coefficients
coef(x)
coef(x, SE = TRUE)
coef(x, SE = TRUE, simplify = TRUE)
coef(x, item = 1, CI = 0)

# fitted values
fitted(x)
fitted(x, item = 1)

# residuals
residuals(x)
residuals(x, item = 1)

# predicted values
predict(x)
predict(x, item = 1)

# predicted values for new subjects
predict(x, item = 1, match = 0, group = c(0, 1))
```

```
# AIC, BIC, log-likelihood
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

# testing both DIF effects using Wald test and
# 3PL model with fixed guessing for groups
difNLR(Data, group, focal.name = 1, model = "3PLcg", test = "W")

# testing both DIF effects using F test and
# 3PL model with fixed guessing for groups
difNLR(Data, group, focal.name = 1, model = "3PLcg", test = "F")

# testing both DIF effects using
# 3PL model with fixed guessing for groups and sandwich estimator
# of the covariance matrices
difNLR(Data, group, focal.name = 1, model = "3PLcg", sandwich = TRUE)

# testing both DIF effects using LR test,
# 3PL model with fixed guessing for groups
# and Benjamini-Hochberg correction
difNLR(Data, group, focal.name = 1, model = "3PLcg", p.adjust.method = "BH")

# testing both DIF effects using LR test,
# 3PL model with fixed guessing for groups
# and item purification
difNLR(Data, group, focal.name = 1, model = "3PLcg", purify = TRUE)

# testing both DIF effects using 3PL model with fixed guessing for groups
# and total score as matching criterion
difNLR(Data, group, focal.name = 1, model = "3PLcg", match = "score")

# testing uniform DIF effects using 4PL model with the same
# guessing and inattention
difNLR(Data, group, focal.name = 1, model = "4PLcgdg", type = "udif")

# testing non-uniform DIF effects using 2PL model
difNLR(Data, group, focal.name = 1, model = "2PL", type = "nudif")

# testing difference in parameter b using 4PL model with fixed
# a and c parameters
difNLR(Data, group, focal.name = 1, model = "4PL", constraints = "ac", type = "b")

# testing both DIF effects using LR test,
# 3PL model with fixed guessing for groups
# using maximum likelihood estimation with
# the L-BFGS-B algorithm, the EM algorithm, and the PLF algorithm
difNLR(Data, group, focal.name = 1, model = "3PLcg", method = "mle")
```

```
difNLR(Data, group, focal.name = 1, model = "3PLcg", method = "em")
difNLR(Data, group, focal.name = 1, model = "3PLcg", method = "plf")

# testing both DIF effects using LR test and 2PL model
# using maximum likelihood estimation with iteratively reweighted least squares algorithm
difNLR(Data, group, focal.name = 1, model = "2PL", method = "irls")

## End(Not run)
```

---

difORD *DIF detection among ordinal data.*

Description

Performs DIF detection procedure for ordinal data based either on adjacent category logit model or on cumulative logit model and likelihood ratio test of a submodel.

Usage

```
difORD(Data, group, focal.name, model = "adjacent", type = "both", match = "zscore",
       anchor = NULL, purify = FALSE, nrIter = 10, p.adjust.method = "none",
       alpha = 0.05, parametrization)
```

Arguments

`Data`	data.frame or matrix: dataset which rows represent ordinally scored examinee answers and columns correspond to the items. In addition, `Data` can hold the vector of group membership.
`group`	numeric or character: a dichotomous vector of the same length as `nrow(Data)` or a column identifier of `Data`.
`focal.name`	numeric or character: indicates the level of `group` which corresponds to focal group.
`model`	character: logistic regression model for ordinal data (either `"adjacent"` (default) or `"cumulative"`). See **Details**.
`type`	character: type of DIF to be tested. Either `"both"` for uniform and non-uniform DIF (default), or `"udif"` for uniform DIF only, or `"nudif"` for non-uniform DIF only. Can be specified as a single value (for all items) or as an item-specific vector.
`match`	numeric or character: matching criterion to be used as an estimate of trait. Can be either `"zscore"` (default, standardized total score), `"score"` (total test score), or vector of the same length as number of observations in `Data`.
`anchor`	numeric or character: specification of DIF free items. Either `NULL` (default), or a vector of item names (column names of `Data`), or item identifiers (integers specifying the column number) determining which items are currently considered as anchor (DIF free) items. Argument is ignored if `match` is not `"zscore"` or `"score"`.

purify logical: should the item purification be applied? (default is FALSE).

nrIter numeric: the maximal number of iterations in the item purification (default is 10).

p.adjust.method
character: method for multiple comparison correction. Possible values are "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", "fdr", and "none" (default). For more details see p.adjust.

alpha numeric: significance level (default is 0.05).

parametrization
deprecated. Use coef.difORD for different parameterizations.

Details

Calculates DIF likelihood ratio statistics based either on adjacent category logit model or on cumulative logit model for ordinal data.

Using adjacent category logit model, logarithm of ratio of probabilities of two adjacent categories is

$$log(P(y = k)/P(y = k-1)) = b_0k + b_1 * x + b_2k * g + b_3 * x : g,$$

where x is by default standardized total score (also called Z-score) and g is a group membership.

Using cumulative logit model, probability of gaining at least k points is given by 2PL model, i.e.,

$$P(y >= k) = exp(b_0k + b_1 * x + b_2k * g + b_3 * x : g)/(1 + exp(b_0k + b_1 * x + b_2k * g + b_3 * x : g)).$$

The category probability (i.e., probability of gaining exactly k points) is then $P(y = k) = P(y >= k) - P(y >= k + 1)$.

Both models are estimated by iteratively reweighted least squares. For more details see vglm.

Missing values are allowed but discarded for item estimation. They must be coded as NA for both, Data and group parameters.

Value

The difORD() function returns an object of class "difORD". The output including values of the test statistics, p-values, and items marked as DIF is displayed by the print() method.

A list of class "difORD" with the following arguments:

Sval the values of likelihood ratio test statistics.

ordPAR the estimates of the final model.

ordSE standard errors of the estimates of the final model.

parM0 the estimates of null model.

parM1 the estimates of alternative model.

llM0 log-likelihood of null model.

llM1 log-likelihood of alternative model.

AICM0 AIC of null model.

AICM1 AIC of alternative model.

`BICM0` BIC of null model.

`BICM1` BIC of alternative model.

`DIFitems` either the column identifiers of the items which were detected as DIF, or `"No DIF item detected"` in case no item was detected as DIF.

`model` model used for DIF detection.

`type` character: type of DIF that was tested.

`purification` `purify` value.

`nrPur` number of iterations in item purification process. Returned only if `purify` is `TRUE`.

`difPur` a binary matrix with one row per iteration of item purification and one column per item. `"1"` in i-th row and j-th column means that j-th item was identified as DIF in i-th iteration. Returned only if `purify` is `TRUE`.

`conv.puri` logical indicating whether item purification process converged before the maximal number `nrIter` of iterations. Returned only if `purify` is `TRUE`.

`p.adjust.method` character: method for multiple comparison correction which was applied.

`pval` the p-values by likelihood ratio test.

`adj.pval` the adjusted p-values by likelihood ratio test using `p.adjust.method`.

`df` the degress of freedom of likelihood ratio test.

`alpha` numeric: significance level.

`Data` the data matrix.

`group` the vector of group membership.

`group.names` levels of grouping variable.

`match` matching criterion.

For an object of class `"difORD"` several methods are available (e.g., `methods(class = "difORD")`).

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

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See Also

`plot.difORD` for graphical representation of item characteristic curves.
`coef.difORD` for extraction of item parameters with their standard errors.
`predict.difORD` for calculation of predicted values.
`logLik.difORD`, `AIC.difORD`, `BIC.difORD` for extraction of log-likelihood and information criteria.

`p.adjust` for multiple comparison corrections.
`vglm` for estimation function using iteratively reweighted least squares.

Examples

```
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects with adjacent category logit model
(x <- difORD(Data, group, focal.name = 1, model = "adjacent"))
## Not run:
# graphical devices
plot(x, item = 6)
plot(x, item = "R6")
plot(x, item = "R6", group.names = c("Males", "Females"))

# estimated parameters
coef(x)
coef(x, SE = TRUE) # with SE
coef(x, SE = TRUE, simplify = TRUE) # with SE, simplified

# AIC, BIC, log-likelihood
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

# testing both DIF effects with Benjamini-Hochberg adjustment method
difORD(Data, group, focal.name = 1, model = "adjacent", p.adjust.method = "BH")

# testing both DIF effects with item purification
difORD(Data, group, focal.name = 1, model = "adjacent", purify = TRUE)

# testing uniform DIF effects
difORD(Data, group, focal.name = 1, model = "adjacent", type = "udif")
# testing non-uniform DIF effects
difORD(Data, group, focal.name = 1, model = "adjacent", type = "nudif")
```

```
# testing both DIF effects with total score as matching criterion
difORD(Data, group, focal.name = 1, model = "adjacent", match = "score")

testing both DIF effects with cumulative logit model
(x <- difORD(Data, group, focal.name = 1, model = "cumulative"))
# graphical devices
plot(x, item = 7, plot.type = "cumulative")
plot(x, item = 7, plot.type = "category")

# estimated parameters
coef(x, simplify = TRUE)

## End(Not run)
```

`estimNLR` *Non-linear regression DIF models estimation.*

Description

Estimates parameters of non-linear regression models for DIF detection using either non-linear least squares or maximum likelihood method with various algorithms.

Usage

```
estimNLR(y, match, group, formula, method, lower, upper, start)

## S3 method for class 'estimNLR'
logLik(object, ...)

## S3 method for class 'estimNLR'
coef(object, ...)

## S3 method for class 'estimNLR'
fitted(object, ...)

## S3 method for class 'estimNLR'
residuals(object, ...)

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

## S3 method for class 'estimNLR'
vcov(object, sandwich = FALSE, ...)
```

Arguments

`y`	numeric: a binary vector of responses ("`1`" correct, "`0`" incorrect).
`match`	numeric: a numeric vector describing the matching criterion.

`group`	numeric: a binary vector of a group membership (`"0"` for the reference group, `"1"` for the focal group).
`formula`	formula: specification of the model. It can be obtained by the `formulaNLR()` function.
`method`	character: an estimation method to be applied. The options are `"nls"` for non-linear least squares (default), `"mle"` for the maximum likelihood method using the `"L-BFGS-B"` algorithm with constraints, `"em"` for the maximum likelihood estimation with the EM algorithm, `"plf"` for the maximum likelihood estimation with the algorithm based on parametric link function, and `"irls"` for the maximum likelihood estimation with the iteratively reweighted least squares algorithm (available for the `"2PL"` model only). See **Details**.
`lower`	numeric: lower bounds for item parameters of the model specified in the `formula`.
`upper`	numeric: upper bounds for item parameters of the model specified in the `formula`.
`start`	numeric: initial values of item parameters. They can be obtained by the `startNLR()` function.
`object`	an object of the `"estimNLR"` class.
`...`	other generic parameters for S3 methods.
`x`	an object of the `"estimNLR"` class.
`sandwich`	logical: should the sandwich estimator be applied for computation of the covariance matrix of item parameters when using `method = "nls"`? (the default is `FALSE`).

Details

The function offers either the non-linear least squares estimation via the `nls` function (Drabinova & Martinkova, 2017; Hladka & Martinkova, 2020), the maximum likelihood method with the `"L-BFGS-B"` algorithm with constraints via the `optim` function (Hladka & Martinkova, 2020), the maximum likelihood method with the EM algorithm (Hladka, Martinkova, & Brabec, 2024), the maximum likelihood method with the algorithm based on parametric link function (PLF; Hladka, Martinkova, & Brabec, 2024), or the maximum likelihood method with the iteratively reweighted least squares algorithm via the `glm` function.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

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Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

Hladka, A. (2021). Statistical models for detection of differential item functioning. Dissertation thesis. Faculty of Mathematics and Physics, Charles University.

Hladka, A., Martinkova, P., & Brabec, M. (2024). New iterative algorithms for estimation of item functioning. Journal of Educational and Behavioral Statistics. Online first, doi:10.3102/10769986241312354.

Examples

```
# loading data
data(GMAT)
y <- GMAT[, 1] # item 1
match <- scale(rowSums(GMAT[, 1:20])) # standardized total score
group <- GMAT[, "group"] # group membership variable

# formula for 3PL model with the same guessing for both groups,
# IRT parameterization
M <- formulaNLR(model = "3PLcg", type = "both", parameterization = "irt")

# starting values for 3PL model with the same guessing for item 1
start <- startNLR(GMAT[, 1:20], group, model = "3PLcg", parameterization = "irt")
start <- start[[1]][M$M1$parameters]

# nonlinear least squares
(fit_nls <- estimNLR(
  y = y, match = match, group = group,
  formula = M$M1$formula, method = "nls",
  lower = M$M1$lower, upper = M$M1$upper, start = start
))

coef(fit_nls)
logLik(fit_nls)
vcov(fit_nls)
vcov(fit_nls, sandwich = TRUE)
fitted(fit_nls)
residuals(fit_nls)

# maximum likelihood method
(fit_mle <- estimNLR(
  y = y, match = match, group = group,
  formula = M$M1$formula, method = "mle",
  lower = M$M1$lower, upper = M$M1$upper, start = start
))

coef(fit_mle)
```

```
logLik(fit_mle)
vcov(fit_mle)
fitted(fit_mle)
residuals(fit_mle)

# formula for 3PL model with the same guessing for both groups
# intercept-slope parameterization
M <- formulaNLR(model = "3PLcg", type = "both", parameterization = "is")

# starting values for 3PL model with the same guessing for item 1,
start <- startNLR(GMAT[, 1:20], group, model = "3PLcg", parameterization = "is")
start <- start[[1]][M$M1$parameters]

# EM algorithm
(fit_em <- estimNLR(
  y = y, match = match, group = group,
  formula = M$M1$formula, method = "em",
  lower = M$M1$lower, upper = M$M1$upper, start = start
))

coef(fit_em)
logLik(fit_em)
vcov(fit_em)
fitted(fit_em)
residuals(fit_em)

# PLF algorithm
(fit_plf <- estimNLR(
  y = y, match = match, group = group,
  formula = M$M1$formula, method = "plf",
  lower = M$M1$lower, upper = M$M1$upper, start = start
))

coef(fit_plf)
logLik(fit_plf)
vcov(fit_plf)
fitted(fit_plf)
residuals(fit_plf)

# iteratively reweighted least squares for 2PL model
M <- formulaNLR(model = "2PL", parameterization = "logistic")
(fit_irls <- estimNLR(
  y = y, match = match, group = group,
  formula = M$M1$formula, method = "irls"
))

coef(fit_irls)
logLik(fit_irls)
vcov(fit_irls)
fitted(fit_irls)
residuals(fit_irls)
```

`fitted.difNLR` *Fitted values and residuals for an object of the* `"difNLR"` *class.*

Description

S3 methods for extracting fitted values and residuals for an object of the `"difNLR"` class.

Usage

```
## S3 method for class 'difNLR'
fitted(object, item = "all", ...)

## S3 method for class 'difNLR'
residuals(object, item = "all", ...)
```

Arguments

`object`	an object of the `"difNLR"` class.
`item`	numeric or character: either character `"all"` to apply for all converged items (default), or a vector of item names (column names of the `Data`), or item identifiers (integers specifying the column number).
`...`	other generic parameters for S3 methods.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

difNLR for DIF detection among binary data using the generalized logistic regression model.
fitted for a generic function extracting fitted values.
residuals for a generic function extracting residuals.

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))

# fitted values
fitted(x)
fitted(x, item = 1)
fitted(x, item = x$DIFitems)

# residuals
residuals(x)
residuals(x, item = 1)
residuals(x, item = x$DIFitems)

## End(Not run)
```

---

formulaNLR *Creates a formula for non-linear regression DIF models.*

Description

The function returns the formula of the non-linear regression DIF model based on model specification and DIF type to be tested.

Usage

```
formulaNLR(model, constraints = NULL, type = "all", parameterization = "irt",
           outcome)
```

Arguments

model	character: generalized logistic regression model for which starting values should be estimated. See **Details**.

`constraints` character: which parameters should be the same for both groups. Possible values are any combinations of parameters `"a"`, `"b"`, `"c"`, and `"d"`. Default value is `NULL`.

`type` character: type of DIF to be tested. Possible values are `"all"` for detecting difference in any parameter (default), `"udif"` for uniform DIF only (i.e., difference in difficulty parameter `"b"`), `"nudif"` for non-uniform DIF only (i.e., difference in discrimination parameter `"a"`), `"both"` for uniform and non-uniform DIF (i.e., difference in parameters `"a"` and `"b"`), or any combination of parameters `"a"`, `"b"`, `"c"`, and `"d"`. Can be specified as a single value (for all items) or as an item-specific vector.

`parameterization`
character: parameterization of regression coefficients. Possible options are `"irt"` (IRT parameterization, default), `"is"` (intercept-slope), and `"logistic"` (logistic regression as in the `glm` function, available for the `"2PL"` model only). See **Details**.

`outcome` character: name of outcome to be printed in formula. If not specified `"y"` is used.

Details

The unconstrained form of the 4PL generalized logistic regression model for probability of correct answer (i.e., $Y_{pi} = 1$) using IRT parameterization is

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(a_i + a_{i\mathrm{DIF}} \cdot G_p) \cdot$$

where X_p is the matching criterion (e.g., standardized total score) and G_p is a group membership variable for respondent p. Parameters a_i, b_i, c_{iR}, and d_{iR} are discrimination, difficulty, guessing, and inattention for the reference group for item i. Terms $a_{i\mathrm{DIF}}$ and $b_{i\mathrm{DIF}}$ then represent differences between the focal and reference groups in discrimination and difficulty for item i. Terms c_{iF}, and d_{iF} are guessing and inattention parameters for the focal group for item i. In the case that there is no assumed difference between the reference and focal group in the guessing or inattention parameters, the terms c_i and d_i are used.

Alternatively, intercept-slope parameterization may be applied:

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(\beta_{i0} + \beta_{i1} \cdot X_p +$$

where parameters $\beta_{i0}, \beta_{i1}, \beta_{i2}, \beta_{i3}$ are intercept, effect of the matching criterion, effect of the group membership, and their mutual interaction, respectively.

The `model` argument offers several predefined models. The options are as follows: `Rasch` for 1PL model with discrimination parameter fixed on value 1 for both groups, `1PL` for 1PL model with discrimination parameter set the same for both groups, `2PL` for logistic regression model, `3PLcg` for 3PL model with fixed guessing for both groups, `3PLdg` for 3PL model with fixed inattention for both groups, `3PLc` (alternatively also `3PL`) for 3PL regression model with guessing parameter, `3PLd` for 3PL model with inattention parameter, `4PLcgdg` for 4PL model with fixed guessing and inattention parameter for both groups, `4PLcgd` (alternatively also `4PLd`) for 4PL model with fixed guessing for both groups, `4PLcdg` (alternatively also `4PLc`) for 4PL model with fixed inattention for both groups, or `4PL` for 4PL model.

Three possible parameterizations can be specified in the `"parameterization"` argument: `"irt"` returns the IRT parameters of the reference group and differences in these parameters between the reference and focal group. Parameters of asymptotes are printed separately for the reference and focal groups. "is" returns intercept-slope parameterization. Parameters of asymptotes are again printed separately for the reference and focal groups. "logistic" returns parameters in logistic regression parameterization as in the glm function, and it is available only for the 2PL model.

Value

A list of two models. Each includes a formula, parameters to be estimated, and their lower and upper constraints.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

difNLR

Examples

```
# 3PL model with the same guessing parameter for both groups
# to test both types of DIF
formulaNLR(model = "3PLcg", type = "both")
formulaNLR(model = "3PLcg", type = "both", parameterization = "is")

# 4PL model with the same guessing and inattention parameters
# to test uniform DIF
formulaNLR(model = "4PLcgdg", type = "udif")
formulaNLR(model = "4PLcgdg", type = "udif", parameterization = "is")

# 2PL model to test non-uniform DIF
formulaNLR(model = "2PL", type = "nudif")
formulaNLR(model = "2PL", type = "nudif", parameterization = "is")
formulaNLR(model = "2PL", type = "nudif", parameterization = "logistic")

# 4PL model to test all possible DIF
formulaNLR(model = "4PL", type = "all", parameterization = "irt")
formulaNLR(model = "4PL", type = "all", parameterization = "is")

# 4PL model with fixed a and c parameters
# to test difference in b
formulaNLR(model = "4PL", constraints = "ac", type = "b")
formulaNLR(model = "4PL", constraints = "ac", type = "b", parameterization = "is")
```

`genNLR` *Generates data set based on generalized logistic regression DIF and DDF models.*

Description

Generates dichotomous, nominal, and ordinal data based on generalized logistic regression models for DIF and DDF detection.

Usage

```
genNLR(N = 1000, ratio = 1, itemtype = "dich", a, b, c, d, mu = 0, sigma = 1)
```

Arguments

`N`	numeric: number of rows representing respondents. (default is 1000).
`ratio`	numeric: ratio of respondents number in reference and focal group.
`itemtype`	character: type of items to be generated. Options are `"dich"` (default) for dichotomous item based on non-linear regression model for DIF detection (see `difNLR` for details), `"nominal"` for nominal items based on multinomial model for DDF detection (see `ddfMLR` for detail), and `"ordinal"` for ordinal data based on adjacent category logit model (for details see `difORD`).
`a`	numeric: matrix representing discriminations with m rows (where m is number of items). Needs to be provided. See **Details**.
`b`	numeric: numeric: matrix representing difficulties with m rows (where m is number of items). Needs to be provided. See **Details**.
`c`	numeric: matrix representing guessings (lower asymptotes) with m rows (where m is number of items). Default is `NULL`. See **Details**.
`d`	numeric: matrix representing inattentions (upper asymptotes) with m rows (where m is number of items). Default is `NULL`. See **Details**.
`mu`	numeric: a mean vector of the underlying distribution. The first value corresponds to reference group, the second to focal group. Default is 0 value for both groups.
`sigma`	numeric: a standard deviation vector of the underlying distribution. The first value corresponds to reference group, the second to focal group. Default is 1 value for both groups.

Details

The `a`, `b`, `c` and `d` are numeric matrices with m rows (where m is number of items) representing parameters of regression models for DIF and DDF detection.

For option `itemtype = "dich"`, matrices should have two columns. The first column represents parameters of the reference group and the second of the focal group. In case that only one column is provided, parameters are set to be the same for both groups.

For options itemtype = "nominal" and itemtype = "ordinal", matrices c and d are ignored. Matrices a and b contain parameters for distractors. For example, when item with 4 different choices is supposed to be generated, user provide matrices with 6 columns. First 3 columns correspond to distractors parameters for reference group and last three columns for focal group. The number of choices can differ for items. Matrices a and b need to consist of as many columns as is the maximum number of distractors. Items with less choices can contain NAs.

Value

A data.frame containing N rows representing respondents and m + 1 columns representing m items. The last column is group membership variable with coding "0" for reference group and "1" for focal group.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

See Also

difNLR, difORD, ddfMLR

Examples

```
# seed
set.seed(123)
# generating parameters for dichotomous data with DIF, 5 items
a <- matrix(runif(10, 0.8, 2), ncol = 2)
b <- matrix(runif(10, -2, 2), ncol = 2)
c <- matrix(runif(10, 0, 0.25), ncol = 2)
d <- matrix(runif(10, 0.8, 1), ncol = 2)
# generating dichotomous data set with 300 observations (150 each group)
genNLR(N = 300, a = a, b = b, c = c, d = d)
# generating dichotomous data set with 300 observations (150 each group)
# and different mean and standard deviation for underlying distribution
genNLR(N = 300, a = a, b = b, c = c, d = d, mu = c(1, 0), sigma = c(1, 2))
# generating dichotomous data set with 300 observations (250 reference group, 50 focal)
```

```
genNLR(N = 300, ratio = 5, a = a, b = b, c = c, d = d)

# generating parameters for nominal data with DDF, 5 items,
# each item 3 choices
a <- matrix(runif(20, 0.8, 2), ncol = 4)
b <- matrix(runif(20, -2, 2), ncol = 4)
# generating nominal data set with 300 observations (150 each group)
genNLR(N = 300, itemtype = "nominal", a = a, b = b)
# generating nominal data set with 300 observations (250 reference group, 50 focal)
genNLR(N = 300, itemtype = "nominal", ratio = 5, a = a, b = b)

# generating parameters for nominal data with DDF, 5 items,
# items 1 and 2 have 2 choices, items 3, 4 and 5 have 3 choices
a <- matrix(runif(20, 0.8, 2), ncol = 4)
a[1:2, c(2, 4)] <- NA
b <- matrix(runif(20, -2, 2), ncol = 4)
b[1:2, c(2, 4)] <- NA
# generating nominal data set with 300 observations (150 each group)
genNLR(N = 300, itemtype = "nominal", a = a, b = b)
# generating nominal data set with 300 observations (250 reference group, 50 focal)
genNLR(N = 300, itemtype = "nominal", ratio = 5, a = a, b = b)
```

GMAT *Dichotomous dataset based on GMAT with the same total score distribution for groups.*

Description

The GMAT is a generated dataset based on parameters from Graduate Management Admission Test (GMAT, Kingston et al., 1985). First two items were considered to function differently in uniform and non-uniform way respectively. The dataset represents responses of 2,000 subjects to multiple-choice test of 20 items. A correct answer is coded as 1 and incorrect answer as 0. The column group represents group membership, where 0 indicates reference group and 1 indicates focal group. Groups are the same size (i.e. 1,000 per group). The distributions of total scores (sum of correct answers) are the same for both reference and focal group (Martinkova et al., 2017). The column criterion represents generated continuous variable which is intended to be predicted by test.

Usage

```
data(GMAT)
```

Format

A GMAT data frame consists of 2,000 observations on the following 22 variables:

Item1-Item20 dichotomously scored items of the test

group group membership vector, "0" reference group, "1" focal group

criterion continuous criterion intended to be predicted by test

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

`GMATtest`, `GMATkey`

GMAT2 — *Dichotomous dataset based on GMAT.*

Description

The `GMAT2` is a generated dataset based on parameters from Graduate Management Admission Test (GMAT, Kingston et al., 1985). First two items were considered to function differently in uniform and non-uniform way respectively. The dataset represents responses of 1,000 subjects to multiple-choice test of 20 items. A correct answer is coded as 1 and incorrect answer as 0. The column `group` represents group membership, where 0 indicates reference group and 1 indicates focal group. Groups are the same size (i.e. 500 per group).

Usage

```
data(GMAT2)
```

Format

A `GMAT2` data frame consists of 1,000 observations on the following 21 variables:

Item1-Item20 dichotomously scored items of the test

group group membership vector, `"0"` reference group, `"1"` focal group

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

GMAT2test, GMAT2key

GMAT2key — *Key of correct answers for* GMAT2test *dataset.*

Description

The GMAT2key is a vector of factors representing correct answers of generated GMAT2test data set based on Graduate Management Admission Test (GMAT) data set (Kingston et al., 1985).

Usage

```
data(GMAT2key)
```

Format

A nominal vector with 20 values representing correct answers to items of GMAT2test dataset. For more details see GMAT2test.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

GMAT2, GMAT2test

GMAT2test — *Dataset based on GMAT.*

Description

The GMAT2test is a generated dataset based on parameters from Graduate Management Admission Test (GMAT, Kingston et al., 1985). First two items were considered to function differently in uniform and non-uniform way respectively. The data set represents responses of 1,000 subjects to multiple-choice test of 20 items. Additionally, 4 possible answers on all items were generated, coded A, B, C, and D. The column group represents group membership, where 0 indicates reference group and 1 indicates focal group. Groups are the same size (i.e. 500 per group).

Usage

```
data(GMAT2test)
```

Format

A GMAT2test data frame consists of 1,000 observations on the following 21 variables:

Item1-Item20 nominal items of the test coded A, B, C, and D

group group membership vector, "0" reference group, "1" focal group

Correct answers are presented in GMAT2key data set.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

GMAT2, GMAT2key

GMATkey *Key of correct answers for* `GMATtest` *dataset.*

Description

The `GMATkey` is a vector of factors representing correct answers of generated `GMATtest` data set based on Graduate Management Admission Test (GMAT, Kingston et al., 1985).

Usage

```
data(GMATkey)
```

Format

A nominal vector with 20 values representing correct answers to items of `GMATtest` dataset. For more details see `GMATtest`.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

`GMAT`, `GMATtest`

`GMATtest` *Dataset based on GMAT with the same total score distribution for groups.*

Description

The `GMATtest` is a generated dataset based on parameters from Graduate Management Admission Test (GMAT, Kingston et al., 1985). First two items were considered to function differently in uniform and non-uniform way respectively. The dataset represents responses of 2,000 subjects to multiple-choice test of 20 items. Additionally, 4 possible answers on all items were generated, coded A, B, C, and D. The column `group` represents group membership, where 0 indicates reference group and 1 indicates focal group. Groups are the same size (i.e. 1,000 per group). The distributions of total scores (sum of correct answers) are the same for both reference and focal group (Martinkova et al., 2017). The column `criterion` represents generated continuous variable which is intended to be predicted by test.

Usage

```
data(GMATtest)
```

Format

A `GMATtest` data frame consists of 2,000 observations on the following 22 variables:

Item1-Item20 nominal items of the test coded A, B, C, and D

group group membership vector, `"0"` reference group, `"1"` focal group

criterion continuous criterion intended to be predicted by test

Correct answers are presented in `GMATkey` data set.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

References

Kingston, N., Leary, L., & Wightman, L. (1985). An exploratory study of the applicability of item response theory methods to the Graduate Management Admission Test. ETS Research Report Series, 1985(2): 1–64.

Martinkova, P., Drabinova, A., Liaw, Y. L., Sanders, E. A., McFarland, J. L., & Price, R. M. (2017). Checking equity: Why differential item functioning analysis should be a routine part of developing conceptual assessments. CBE–Life Sciences Education, 16(2), rm2, doi:10.1187/cbe.16100307.

See Also

`GMAT`, `GMATkey`

`logLik.ddfMLR` *Log-likelihood and information criteria for an object of* `"ddfMLR"` *class.*

Description

S3 methods for extracting log-likelihood, Akaike's information criterion (AIC) and Schwarz's Bayesian criterion (BIC) for an object of `"ddfMLR"` class.

Usage

```
## S3 method for class 'ddfMLR'
logLik(object, item = "all", ...)

## S3 method for class 'ddfMLR'
AIC(object, item = "all", ...)

## S3 method for class 'ddfMLR'
BIC(object, item = "all", ...)
```

Arguments

object	an object of "ddfMLR" class.
item	numeric or character: either character "all" to apply for all converged items (default), or a vector of item names (column names of Data), or item identifiers (integers specifying the column number).
...	other generic parameters for S3 methods.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

ddfMLR for DDF detection among nominal data.
logLik for generic function extracting log-likelihood.
AIC for generic function calculating AIC and BIC.

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
(x <- ddfMLR(Data, group, focal.name = 1, key))

# AIC, BIC, log-likelihood
```

```
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

## End(Not run)
```

`logLik.difNLR` *Log-likelihood and information criteria for an object of the* `"difNLR"` *class.*

Description

S3 methods for extracting log-likelihood, Akaike's information criterion (AIC) and Schwarz's Bayesian criterion (BIC) for an object of the `"difNLR"` class.

Usage

```
## S3 method for class 'difNLR'
logLik(object, item = "all", ...)

## S3 method for class 'difNLR'
AIC(object, item = "all", ...)

## S3 method for class 'difNLR'
BIC(object, item = "all", ...)
```

Arguments

`object`	an object of the `"difNLR"` class.
`item`	numeric or character: either character `"all"` to apply for all converged items (default), or a vector of item names (column names of the `Data`), or item identifiers (integers specifying the column number).
`...`	other generic parameters for S3 methods.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences

<martinkova@cs.cas.cz>

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`difNLR` for DIF detection among binary data using the generalized logistic regression model.
`logLik` for a generic function extracting log-likelihood.
`AIC` for a generic function calculating AIC and BIC.

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))

# AIC, BIC, log-likelihood
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

## End(Not run)
```

logLik.difORD *Log-likelihood and information criteria for an object of* "difORD" *class.*

Description

S3 methods for extracting log-likelihood, Akaike's information criterion (AIC) and Schwarz's Bayesian criterion (BIC) for an object of "difORD" class.

Usage

```
## S3 method for class 'difORD'
logLik(object, item = "all", ...)

## S3 method for class 'difORD'
AIC(object, item = "all", ...)

## S3 method for class 'difORD'
BIC(object, item = "all", ...)
```

Arguments

object	an object of "difORD" class.
item	numeric or character: either character "all" to apply for all converged items (default), or a vector of item names (column names of Data), or item identifiers (integers specifying the column number).
...	other generic parameters for S3 methods.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

difORD for DIF detection among ordinal data.
logLik for generic function extracting log-likelihood.
AIC for generic function calculating AIC and BIC.

Examples

```
## Not run:
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects with adjacent category logit model
(x <- difORD(Data, group, focal.name = 1, model = "adjacent"))

# AIC, BIC, log-likelihood
AIC(x)
BIC(x)
logLik(x)

# AIC, BIC, log-likelihood for the first item
AIC(x, item = 1)
BIC(x, item = 1)
logLik(x, item = 1)

## End(Not run)
```

MLR — *DDF likelihood ratio statistics based on multinomial log-linear regression model.*

Description

Calculates DDF likelihood ratio statistics for nominal data based on multinomial log-linear model.

Usage

```
MLR(Data, group, key, type = "both", match = "zscore", anchor = 1:ncol(Data),
    p.adjust.method = "none", alpha = 0.05, parametrization)
```

Arguments

`Data`	data.frame or matrix: dataset which rows represent unscored examinee answers (nominal) and columns correspond to the items.
`group`	numeric: binary vector of group membership. `"0"` for reference group, `"1"` for focal group.
`key`	character: the answer key. Each element corresponds to the correct answer of one item.
`type`	character: type of DDF to be tested. Either `"both"` for uniform and non-uniform DDF (i.e., difference in parameters `"a"` and `"b"`) (default), or `"udif"` for uniform DDF only (i.e., difference in difficulty parameter `"b"`), or `"nudif"` for non-uniform DDF only (i.e., difference in discrimination parameter `"a"`). Can be specified as a single value (for all items) or as an item-specific vector.

match — numeric or character: matching criterion to be used as an estimate of trait. Can be either "zscore" (default, standardized total score), "score" (total test score), or vector of the same length as number of observations in Data.

anchor — character or numeric: specification of DIF free items. A vector of item identifiers (integers specifying the column number) specifying which items are currently considered as anchor (DIF free) items. Argument is ignored if match is not "zscore" or "score".

p.adjust.method — character: method for multiple comparison correction. Possible values are "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", "fdr", and "none" (default). For more details see p.adjust.

alpha — numeric: significance level (default is 0.05).

parametrization — deprecated. Use coef.ddfMLR for different parameterizations.

Details

$$P(y = k) = exp(b_0 k + b_1 k * x + b_2 k * g + b_3 k * x * g)/(1 + \sum exp(b_0 l + b_1 l * x + b_2 l * g + b_3 l * x * g)),$$

where x is by default standardized total score (also called Z-score) and g is a group membership. Probability of correct answer (specified in argument key) is

$$P(y = k) = 1/(1 + \sum exp(b_0 l + b_1 l * x + b_2 l * g + b_3 l * x * g)).$$

Parameters are estimated via neural networks. For more details see multinom.

Value

A list with the following arguments:

Sval the values of likelihood ratio test statistics.

pval the p-values by likelihood ratio test.

adj.pval the adjusted p-values by likelihood ratio test using p.adjust.method.

df the degress of freedom of likelihood ratio test.

par.m0 the estimates of null model.

par.m1 the estimates of alternative model.

se.m0 standard errors of parameters in null model.

se.m1 standard errors of parameters in alternative model.

cov.m0 list of covariance matrices of item parameters for null model.

cov.m1 list of covariance matrices of item parameters for alternative model.

ll.m0 log-likelihood of m0 model.

ll.m1 log-likelihood of m1 model.

AIC.m0 AIC of m0 model.

AIC.m1 AIC of m1 model.

BIC.m0 BIC of m0 model.

BIC.m1 BIC of m1 model.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

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Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

p.adjust multinom

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
MLR(Data, group, key, type = "both")

# testing uniform DDF effects
MLR(Data, group, key, type = "udif")

# testing non-uniform DDF effects
MLR(Data, group, key, type = "nudif")

## End(Not run)
```

MSATB *Dichotomous dataset of Medical School Admission Test in Biology.*

Description

The MSATB dataset consists of the responses of 1,407 subjects (484 males, 923 females) to admission test to medical school in the Czech republic. It contains 20 selected items from original test while first item was previously detected as differently functioning (Vlckova, 2014). A correct answer is coded as 1 and incorrect answer as 0. The column gender represents gender of students, where 0 indicates males (reference group) and 1 indicates females (focal group).

Usage

```
data(MSATB)
```

Format

A MSATB data frame consists of 1,407 observations on the following 21 variables:

Item dichotomously scored items of the test

gender gender of respondents, "0" males, "1" females

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Vlckova, K. (2014). Test and item fairness. Master's thesis. Faculty of Mathematics and Physics, Charles University.

See Also

MSATBtest, MSATBkey

MSATBkey *Key of correct answers for* MSATBtest *dataset.*

Description

The MSATBkey is a vector of factors representing correct answers of MSATBtest dataset.

Usage

```
data(MSATBkey)
```

Format

A nominal vector with 20 values representing correct answers to items of MSATBtest dataset. For more details see MSATBtest.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Vlckova, K. (2014). Test and item fairness. Master's thesis. Faculty of Mathematics and Physics, Charles University.

See Also

MSATB, MSATBtest

MSATBtest *Dataset of School Admission Test in Biology.*

Description

The MSATBtest dataset consists of the responses of 1,407 subjects (484 males, 923 females) to multiple-choice admission test to medical school in the Czech republic. It contains 20 selected items from original test while first item was previously detected detected as differently functioning (Vlckova, 2014). Possible answers were A, B, C, and D, while any combination of these can be correct. The column gender represents gender of students, where 0 indicates males (reference group) and 1 indicates females (focal group).

Usage

```
data(MSATBtest)
```

Format

A MSATBtest data frame consists of 1,407 observations on the following 21 variables:

Item nominal items of the test

gender gender of respondents, "0" males, "1" females

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Vlckova, K. (2014). Test and item fairness. Master's thesis. Faculty of Mathematics and Physics, Charles University.

See Also

MSATB, MSATBkey

NLR *DIF statistics for non-linear regression models.*

Description

Calculates likelihood ratio test statistics, F-test statistics, or Wald's test statistics for DIF detection among dichotomous items using non-linear regression models (generalized logistic regression models).

Usage

```
NLR(Data, group, model, constraints = NULL, type = "all", method = "nls",
    match = "zscore", anchor = 1:ncol(Data), start, p.adjust.method = "none",
    test = "LR", alpha = 0.05, initboot = TRUE, nrBo = 20, sandwich = FALSE)
```

Arguments

`Data`	data.frame or matrix: dataset in which rows represent scored examinee answers (`"1"` correct, `"0"` incorrect) and columns correspond to the items.
`group`	numeric: a binary vector of a group membership (`"0"` for the reference group, `"1"` for the focal group).
`model`	character: generalized logistic regression model to be fitted. See **Details**.
`constraints`	character: which parameters should be the same for both groups. Possible values are any combinations of parameters `"a"`, `"b"`, `"c"`, and `"d"`. Default value is `NULL`. See **Details**.
`type`	character: type of DIF to be tested. Possible values are `"all"` for detecting difference in any parameter (default), `"udif"` for uniform DIF only (i.e., difference in difficulty parameter `"b"`), `"nudif"` for non-uniform DIF only (i.e., difference in discrimination parameter `"a"`), `"both"` for uniform and non-uniform DIF (i.e., difference in parameters `"a"` and `"b"`), or any combination of parameters `"a"`, `"b"`, `"c"`, and `"d"`. Can be specified as a single value (for all items) or as an item-specific vector.
`method`	character: an estimation method to be applied. The options are `"nls"` for non-linear least squares (default), `"mle"` for the maximum likelihood method using the `"L-BFGS-B"` algorithm with constraints, `"em"` for the maximum likelihood estimation with the EM algorithm, `"plf"` for the maximum likelihood estimation with the algorithm based on parametric link function, and `"irls"` for the maximum likelihood estimation with the iteratively reweighted least squares algorithm (available for the `"2PL"` model only). See **Details**.
`match`	character or numeric: matching criterion to be used as an estimate of the trait. It can be either `"zscore"` (default, standardized total score), `"score"` (total test score), or a numeric vector of the same length as a number of observations in the `Data`.

anchor
: character or numeric: specification of DIF free items. A vector of item identifiers (integers specifying the column number) specifying which items are currently considered as anchor (DIF free) items. Argument is ignored if the `match` is not `"zscore"` or `"score"`.

start
: numeric: initial values for the estimation of item parameters. If not specified, starting values are calculated with the `startNLR` function. Otherwise, a list with as many elements as a number of items. Each element is a named numeric vector representing initial values for estimation of item parameters. Specifically, parameters `"a"`, `"b"`, `"c"`, and `"d"` are initial values for discrimination, difficulty, guessing, and inattention for the reference group. Parameters `"aDif"`, `"bDif"`, `"cDif"`, and `"dDif"` are then differences in these parameters between the reference and focal groups. For the `method = "irls"`, default initial values from the `glm` function are used.

p.adjust.method
: character: a method for a multiple comparison correction. Possible values are `"holm"`, `"hochberg"`, `"hommel"`, `"bonferroni"`, `"BH"`, `"BY"`, `"fdr"`, and `"none"` (default). For more details see `p.adjust`.

test
: character: a statistical test to be performed for DIF detection. Can be either `"LR"` for the likelihood ratio test of a submodel (default), `"W"` for the Wald's test, or `"F"` for the F-test of a submodel.

alpha
: numeric: a significance level (the default is 0.05).

initboot
: logical: in the case of convergence issues, should starting values be re-calculated based on bootstrapped samples? (the default is `TRUE`; newly calculated initial values are applied only to items/models with convergence issues).

nrBo
: numeric: the maximal number of iterations for the calculation of starting values using bootstrapped samples (the default is 20).

sandwich
: logical: should the sandwich estimator be applied for computation of the covariance matrix of item parameters when using `method = "nls"`? (the default is `FALSE`).

Details

The function calculates test statistics using a DIF detection procedure based on non-linear regression models (i.e., extensions of the logistic regression procedure; Swaminathan & Rogers, 1990; Drabinova & Martinkova, 2017).

The unconstrained form of the 4PL generalized logistic regression model for probability of correct answer (i.e., $Y_{pi} = 1$) using IRT parameterization is

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(a_i + a_{i\mathrm{DIF}} \cdot G_p) \cdot$$

where X_p is the matching criterion (e.g., standardized total score) and G_p is a group membership variable for respondent p. Parameters a_i, b_i, c_{iR}, and d_{iR} are discrimination, difficulty, guessing, and inattention for the reference group for item i. Terms $a_{i\mathrm{DIF}}$ and $b_{i\mathrm{DIF}}$ then represent differences between the focal and reference groups in discrimination and difficulty for item i. Terms c_{iF}, and d_{iF} are guessing and inattention parameters for the focal group for item i. In the case that there is no assumed difference between the reference and focal group in the guessing or inattention parameters, the terms c_i and d_i are used.

Alternatively, intercept-slope parameterization may be applied:

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(\beta_{i0} + \beta_{i1} \cdot X_p +$$

where parameters $\beta_{i0}, \beta_{i1}, \beta_{i2}, \beta_{i3}$ are intercept, effect of the matching criterion, effect of the group membership, and their mutual interaction, respectively.

The `model` and `constraints` arguments can further constrain the 4PL model. The arguments `model` and `constraints` can also be combined. Both arguments can be specified as a single value (for all items) or as an item-specific vector (where each element corresponds to one item).

The `model` argument offers several predefined models. The options are as follows: `Rasch` for 1PL model with discrimination parameter fixed on value 1 for both groups, `1PL` for 1PL model with discrimination parameter set the same for both groups, `2PL` for logistic regression model, `3PLcg` for 3PL model with fixed guessing for both groups, `3PLdg` for 3PL model with fixed inattention for both groups, `3PLc` (alternatively also `3PL`) for 3PL regression model with guessing parameter, `3PLd` for 3PL model with inattention parameter, `4PLcgdg` for 4PL model with fixed guessing and inattention parameter for both groups, `4PLcgd` (alternatively also `4PLd`) for 4PL model with fixed guessing for both groups, `4PLcdg` (alternatively also `4PLc`) for 4PL model with fixed inattention for both groups, or `4PL` for 4PL model.

The function uses intercept-slope parameterization for the estimation via the `estimNLR` function. Item parameters are then re-calculated into the IRT parameterization using the delta method.

The function offers either the non-linear least squares estimation via the `nls` function (Drabinova & Martinkova, 2017; Hladka & Martinkova, 2020), the maximum likelihood method with the `"L-BFGS-B"` algorithm with constraints via the `optim` function (Hladka & Martinkova, 2020), the maximum likelihood method with the EM algorithm (Hladka, Martinkova, & Brabec, 2024), the maximum likelihood method with the algorithm based on parametric link function (PLF, the default option; Hladka, Martinkova, & Brabec, 2024), or the maximum likelihood method with the iteratively reweighted least squares algorithm via the `glm` function.

Value

A list with the following arguments:

`Sval` the values of the `test` statistics.

`pval` the p-values by the `test`.

`adjusted.pval` adjusted p-values by the `p.adjust.method`.

`df` the degrees of freedom of the `test`.

`test` used test.

`par.m0` the matrix of estimated item parameters for the null model.

`se.m0` the matrix of standard errors of item parameters for the null model.

`cov.m0` list of covariance matrices of item parameters for the null model.

`par.m1` the matrix of estimated item parameters for the alternative model.

`se.m1` the matrix of standard errors of item parameters for the alternative model.

`cov.m1` list of covariance matrices of item parameters for the alternative model.

`cf` numeric: a number of convergence issues.

`cf.which` the indicators of the items that did not converge.

`ll.m0` log-likelihood of null model.

`ll.m1` log-likelihood of alternative model.

`startBo0` the binary matrix. Columns represent iterations of initial values re-calculations, rows represent items. The value of 0 means no convergence issue in the null model, 1 means convergence issue in the null model.

`startBo1` the binary matrix. Columns represent iterations of initial values re-calculations, rows represent items. The value of 0 means no convergence issue in the alternative model, 1 means convergence issue in the alternative model.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

Karel Zvara
Faculty of Mathematics and Physics, Charles University

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Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

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Swaminathan, H. & Rogers, H. J. (1990). Detecting differential item functioning using logistic regression procedures. Journal of Educational Measurement, 27(4), 361–370, doi:10.1111/j.1745-3984.1990.tb00754.x

See Also

`p.adjust`

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using the LR test (default)
# and the model with fixed guessing for both groups
NLR(Data, group, model = "3PLcg")

# using the F test and Wald's test
NLR(Data, group, model = "3PLcg", test = "F")
NLR(Data, group, model = "3PLcg", test = "W")

# using the Benjamini-Hochberg correction
NLR(Data, group, model = "3PLcg", p.adjust.method = "BH")

# 4PL model with the same guessing and inattention
# to test uniform DIF
NLR(Data, group, model = "4PLcgdg", type = "udif")

# 2PL model to test non-uniform DIF
NLR(Data, group, model = "2PL", type = "nudif")

# 4PL model with fixed a and c parameters
# to test difference in parameter b
NLR(Data, group, model = "4PL", constraints = "ac", type = "b")

# using various estimation algorithms
NLR(Data, group, model = "3PLcg", method = "nls")
NLR(Data, group, model = "3PLcg", method = "mle")
NLR(Data, group, model = "3PLcg", method = "em")
NLR(Data, group, model = "3PLcg", method = "plf")
NLR(Data, group, model = "2PL", method = "irls")

## End(Not run)
```

ORD *DIF likelihood ratio statistics for ordinal data.*

Description

Calculates DIF likelihood ratio statistics for ordinal data based either on adjacent category logit regression model or on cumulative logit regression model.

Usage

```
ORD(Data, group, model = "adjacent", type = "both", match = "zscore",
    anchor = 1:ncol(Data), p.adjust.method = "none",
    alpha = 0.05, parametrization)
```

Arguments

- `Data` data.frame or matrix: dataset which rows represent ordinally scored examinee answers and columns correspond to the items.
- `group` numeric: binary vector of group membership. `"0"` for reference group, `"1"` for focal group.
- `model` character: logistic regression model for ordinal data (either `"adjacent"` (default) or `"cumulative"`). See **Details**.
- `type` character: type of DIF to be tested. Either `"both"` for uniform and non-uniform DIF (i.e., difference in parameters `"a"` and `"b"`) (default), or `"udif"` for uniform DIF only (i.e., difference in difficulty parameter `"b"`), or `"nudif"` for non-uniform DIF only (i.e., difference in discrimination parameter `"a"`). Can be specified as a single value (for all items) or as an item-specific vector.
- `match` numeric or character: matching criterion to be used as an estimate of trait. Can be either `"zscore"` (default, standardized total score), `"score"` (total test score), or vector of the same length as number of observations in `Data`.
- `anchor` character or numeric: specification of DIF free items. A vector of item identifiers (integers specifying the column number) specifying which items are currently considered as anchor (DIF free) items. Argument is ignored if `match` is not `"zscore"` or `"score"`.
- `p.adjust.method` character: method for multiple comparison correction. Possible values are `"holm"`, `"hochberg"`, `"hommel"`, `"bonferroni"`, `"BH"`, `"BY"`, `"fdr"`, and `"none"` (default). For more details see `p.adjust`.
- `alpha` numeric: significance level (default is 0.05).
- `parametrization` deprecated. Use `coef.difORD` for different parameterizations.

Details

Calculates DIF likelihood ratio statistics based either on adjacent category logit model or on cumulative logit model for ordinal data.

Using adjacent category logit model, logarithm of ratio of probabilities of two adjacent categories is

$$log(P(y = k)/P(y = k - 1)) = b_0k + b_1 * x + b_2k * g + b_3 * x : g,$$

where x is by default standardized total score (also called Z-score) and g is a group membership.

Using cumulative logit model, probability of gaining at least k points is given by 2PL model, i.e.,

$$P(y >= k) = exp(b_0k + b_1 * x + b_2k * g + b_3 * x : g)/(1 + exp(b_0k + b_1 * x + b_2k * g + b_3 * x : g)).$$

The category probability (i.e., probability of gaining exactly k points) is then $P(y = k) = P(y >= k) - P(y >= k + 1)$.

Both models are estimated by iteratively reweighted least squares. For more details see `vglm`.

Value

A list with the following arguments:

`Sval` the values of likelihood ratio test statistics.

`pval` the p-values by likelihood ratio test.

`adj.pval` the adjusted p-values by likelihood ratio test using `p.adjust.method`.

`df` the degress of freedom of likelihood ratio test.

`par.m0` the estimates of null model.

`par.m1` the estimates of alternative model.

`se.m0` standard errors of parameters in null model.

`se.m1` standard errors of parameters in alternative model.

`cov.m0` list of covariance matrices of item parameters for null model.

`cov.m1` list of covariance matrices of item parameters for alternative model.

`ll.m0` log-likelihood of null model.

`ll.m1` log-likelihood of alternative model.

`AIC.m0` AIC of null model.

`AIC.m1` AIC of alternative model.

`BIC.m0` BIC of null model.

`BIC.m1` BIC of alternative model.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

References

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Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`p.adjust` `vglm`

Examples

```
## Not run:
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects
ORD(Data, group, type = "both")

# testing uniform DIF effects
ORD(Data, group, type = "udif")

# testing non-uniform DIF effects
ORD(Data, group, type = "nudif")

# testing DIF using cumulative logit model
ORD(Data, group, model = "cumulative")

## End(Not run)
```

---

plot.ddfMLR *ICC plots for an object of* "ddfMLR" *class.*

Description

Plot method for an object of "ddfMLR" class using **ggplot2**.

The characteristic curves for an item specified in item argument are plotted. Plotted curves represent the best model.

Usage

```
## S3 method for class 'ddfMLR'
plot(x, item = "all", group.names, ...)
```

Arguments

x	an object of "ddfMLR" class.
item	numeric or character: either character "all" to apply for all items (default), or a vector of item names (column names of Data), or item identifiers (integers specifying the column number).
group.names	character: names of reference and focal group.
...	other generic parameters for plot() function.

Value

Returns list of objects of class "ggplot".

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

See Also

ddfMLR for DDF detection.
ggplot for general function to plot a "ggplot" object.

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
(x <- ddfMLR(Data, group, focal.name = 1, key))

# graphical devices
plot(x, item = "Item1", group.names = c("Group 1", "Group 2"))
plot(x, item = x$DDFitems)
plot(x, item = c(3, 1, 5))

## End(Not run)
```

---

plot.difNLR *ICC and test statistics plots for an object of the "difNLR" class.*

Description

A plotting method for an object of the "difNLR" class using the **ggplot2** package.

Two types of plots are available. The first one is obtained by setting plot.type = "cc" (default). The characteristic curves for items specified in the item argument are plotted. Plotted curves represent the best fitted model.

The second plot is obtained by setting plot.type = "stat". The test statistics (either LR-test, F-test, or Wald test; depending on argument test) are displayed on the Y axis, for each converged item. The detection threshold is displayed by a horizontal line and items detected as DIF are printed with the red color. Only parameters size and title are used.

Usage

```
## S3 method for class 'difNLR'
plot(
  x,
  plot.type = "cc",
  item = "all",
  group.names,
  draw.empirical = TRUE,
  draw.CI = FALSE,
  ...
)
```

Arguments

x	an object of the "difNLR" class.
plot.type	character: a type of a plot to be plotted (either "cc" for characteristic curves (default), or "stat" for test statistics).
item	numeric or character: either character "all" to apply for all converged items (default), or a vector of item names (column names of the Data), or item identifiers (integers specifying the column number).
group.names	character: names of the reference and focal groups.
draw.empirical	logical: should empirical probabilities be plotted as points? (the default value is TRUE).
draw.CI	logical: should confidence intervals for predicted values be plotted? (the default value is FALSE).
...	other generic parameters for the plot() method.

Value

For an option plot.type = "stat", returns object of the "ggplot" class. In the case of plot.type = "cc", returns a list of objects of the "ggplot" class.

Outputs can be edited and modified as a standard "ggplot" object including colours, titles, shapes, or linetypes.

Note that the option draw.CI = TRUE returns confidence intervals for predicted values as calculated by the predict.difNLR. Confidence intervals may overlap even in the case that item functions differently.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences

<martinkova@cs.cas.cz>

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`difNLR` for DIF detection among binary data using the generalized logistic regression model. `predict.difNLR` for prediction. `ggplot` for a general function to plot with the **"ggplot2"** package.

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))

# item characteristic curves
plot(x)
plot(x, item = x$DIFitems)
plot(x, item = 1)
plot(x, item = "Item2", group.names = c("Group 1", "Group 2"))

# item characteristic curves without empirical probabilities
plot(x, item = 1, draw.empirical = FALSE)

# item characteristic curves without empirical probabilities but with CI
plot(x, item = 1, draw.empirical = FALSE, draw.CI = TRUE)

# graphical devices - test statistics
plot(x, plot.type = "stat")

## End(Not run)
```

`plot.difORD` *ICC plots for an object of* `"difORD"` *class.*

Description

Plot method for an object of `"difORD"` class using **ggplot2**.

The characteristic curves (category probabilities) for an item specified in `item` argument are plotted. Plotted curves represent the best model. For cumulative logit model, also cumulative probabilities may be plotted.

Usage

```
## S3 method for class 'difORD'
plot(x, item = "all", plot.type, group.names, ...)
```

Arguments

`x`	an object of `"difORD"` class.
`item`	numeric or character: either character `"all"` to apply for all converged items (default), or a vector of item names (column names of `Data`), or item identifiers (integers specifying the column number).
`plot.type`	character: which plot should be displayed for cumulative logit regression model. Either `"category"` (default) for category probabilities or `"cumulative"` for cumulative probabilities.
`group.names`	character: names of reference and focal group.
`...`	other generic parameters for `plot()` function.

Value

Returns list of objects of class `"ggplot"`.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
Faculty of Mathematics and Physics, Charles University
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

See Also

`difORD` for DIF detection among ordinal data.
`ggplot` for general function to plot a `"ggplot"` object.

Examples

```
## Not run:
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects with adjacent category logit model
(x <- difORD(Data, group, focal.name = 1, model = "adjacent"))

# graphical devices
plot(x, item = 6)
plot(x, item = "R6", group.names = c("Males", "Females"))

# testing both DIF effects with cumulative logit model
(x <- difORD(Data, group, focal.name = 1, model = "cumulative"))
plot(x, item = 7, plot.type = "cumulative")
plot(x, item = 7, plot.type = "category")

## End(Not run)
```

---

predict.ddfMLR — *Predicted values for an object of* "ddfMLR" *class.*

Description

S3 method for predictions from the model used in the object of "ddfMLR" class.

Usage

```
## S3 method for class 'ddfMLR'
predict(object, item = "all", match, group, ...)
```

Arguments

object	an object of "ddfMLR" class.
item	numeric or character: either character "all" to apply for all converged items (default), or a vector of item names (column names of Data), or item identifiers (integers specifying the column number).
match	numeric: matching criterion for new observations.
group	numeric: group membership for new observations.
...	other generic parameters for predict() function.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`ddfMLR` for DDF detection among nominal data using multinomial log-linear regression model.
`predict` for generic function for prediction.

Examples

```
## Not run:
# loading data
data(GMATtest, GMATkey)
Data <- GMATtest[, 1:20] # items
group <- GMATtest[, "group"] # group membership variable
key <- GMATkey # correct answers

# testing both DDF effects
(x <- ddfMLR(Data, group, focal.name = 1, key))

# fitted values
predict(x, item = 1)

# predicted values
predict(x, item = 1, match = 0, group = c(0, 1))
predict(x, item = x$DDFitems, match = 0, group = c(0, 1))

## End(Not run)
```

`predict.difNLR` *Predicted values for an object of the* `"difNLR"` *class.*

Description

S3 method for predictions from the fitted model used in the object of the `"difNLR"` class.

Usage

```
## S3 method for class 'difNLR'
predict(object, item = "all", match, group, interval = "none", CI = 0.95, ...)
```

Arguments

`object`	an object of the `"difNLR"` class.
`item`	numeric or character: either character `"all"` to apply for all converged items (default), or a vector of item names (column names of the `Data`), or item identifiers (integers specifying the column number).
`match`	numeric: a matching criterion for new observations.
`group`	numeric: a group membership variable for new observations.
`interval`	character: a type of interval calculation, either `"none"` (default) or `"confidence"` for confidence interval.
`CI`	numeric: a significance level for confidence interval (the default is `0.95` for 95% confidence interval).
`...`	other generic parameters for the `predict()` method.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

Karel Zvara
Faculty of Mathematics and Physics, Charles University

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`difNLR` for DIF detection among binary data using the generalized logistic regression model.
`predict` for a generic function for prediction.

Examples

```
## Not run:
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# testing both DIF effects using likelihood-ratio test and
# 3PL model with fixed guessing for groups
(x <- difNLR(Data, group, focal.name = 1, model = "3PLcg"))

# predicted values
summary(predict(x))
predict(x, item = 1)
predict(x, item = "Item1")

# predicted values for new observations - average score
predict(x, item = 1, match = 0, group = 0) # reference group
predict(x, item = 1, match = 0, group = 1) # focal group
predict(x, item = 1, match = 0, group = c(0, 1)) # both groups

# predicted values for new observations - various Z-scores and groups
new.match <- rep(c(-1, 0, 1), each = 2)
new.group <- rep(c(0, 1), 3)
predict(x, item = 1, match = new.match, group = new.group)

# predicted values for new observations with confidence intervals
predict(x, item = 1, match = new.match, group = new.group, interval = "confidence")
predict(x, item = c(2, 4), match = new.match, group = new.group, interval = "confidence")

## End(Not run)
```

`predict.difORD` *Predicted values for an object of* `"difORD"` *class.*

Description

S3 method for predictions from the model used in the object of `"difORD"` class.

Usage

```
## S3 method for class 'difORD'
predict(object, item = "all", match, group, type = "category", ...)
```

Arguments

`object` an object of `"difORD"` class.

`item`	numeric or character: either character "all" to apply for all converged items (default), or a vector of item names (column names of `Data`), or item identifiers (integers specifying the column number).
`match`	numeric: matching criterion for new observations.
`group`	numeric: group membership for new observations.
`type`	character: type of probability to be computed. Either "category" for category probabilities or "cumulative" for cumulative probabilities. Cumulative probabilities are available only for cumulative logit model.
`...`	other generic parameters for `predict()` function.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
<hladka@cs.cas.cz>

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
<martinkova@cs.cas.cz>

References

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

See Also

`difORD` for DIF detection among ordinal data using either cumulative logit or adjacent category logit model.
`predict` for generic function for prediction.

Examples

```
## Not run:
# loading data
data(Anxiety, package = "ShinyItemAnalysis")
Data <- Anxiety[, paste0("R", 1:29)] # items
group <- Anxiety[, "gender"] # group membership variable

# testing both DIF effects with cumulative logit model
(x <- difORD(Data, group, focal.name = 1, model = "cumulative"))

# fitted values
predict(x, item = "R6")

# predicted values
predict(x, item = "R6", match = 0, group = c(0, 1))
predict(x, item = "R6", match = 0, group = c(0, 1), type = "cumulative")
```

```
predict(x, item = c("R6", "R7"), match = 0, group = c(0, 1))

# testing both DIF effects with adjacent category logit model
(x <- difORD(Data, group, focal.name = 1, model = "adjacent"))

# fitted values
predict(x, item = "R6")

# predicted values
predict(x, item = "R6", match = 0, group = c(0, 1))
predict(x, item = c("R6", "R7"), match = 0, group = c(0, 1))

## End(Not run)
```

---

startNLR *Calculates starting values for non-linear regression DIF models.*

Description

Calculates starting values for the difNLR() function based on linear approximation.

Usage

```
startNLR(Data, group, model, constraints = NULL, match = "zscore",
         parameterization = "irt", simplify = FALSE)
```

Arguments

Data — data.frame or matrix: dataset in which rows represent scored examinee answers ("1" correct, "0" incorrect) and columns correspond to the items.

group — numeric: a binary vector of a group membership ("0" for the reference group, "1" for the focal group).

model — character: generalized logistic regression model for which starting values should be estimated. See **Details**.

constraints — character: which parameters should be the same for both groups. Possible values are any combinations of parameters "a", "b", "c", and "d". Default value is NULL.

match — character or numeric: matching criterion to be used as an estimate of the trait. It can be either "zscore" (default, standardized total score), "score" (total test score), or a numeric vector of the same length as a number of observations in the Data.

parameterization — character: parameterization of regression coefficients. Possible options are "irt" (IRT parameterization, default), "is" (intercept-slope), and "logistic" (logistic regression as in the glm function, available for the "2PL" model only). See **Details**.

simplify — logical: should initial values be simplified into the matrix? It is only applicable when parameterization is the same for all items.

Details

The unconstrained form of the 4PL generalized logistic regression model for probability of correct answer (i.e., $Y_{pi} = 1$) using IRT parameterization is

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(a_i + a_{i\mathrm{DIF}} \cdot G_p) \cdot$$

where X_p is the matching criterion (e.g., standardized total score) and G_p is a group membership variable for respondent p. Parameters a_i, b_i, c_{iR}, and d_{iR} are discrimination, difficulty, guessing, and inattention for the reference group for item i. Terms $a_{i\mathrm{DIF}}$ and $b_{i\mathrm{DIF}}$ then represent differences between the focal and reference groups in discrimination and difficulty for item i. Terms c_{iF}, and d_{iF} are guessing and inattention parameters for the focal group for item i. In the case that there is no assumed difference between the reference and focal group in the guessing or inattention parameters, the terms c_i and d_i are used.

Alternatively, intercept-slope parameterization may be applied:

$$P(Y_{pi} = 1|X_p, G_p) = (c_{iR} \cdot G_p + c_{iF} \cdot (1 - G_p)) + (d_{iR} \cdot G_p + d_{iF} \cdot (1 - G_p) - c_{iR} \cdot G_p - c_{iF} \cdot (1 - G_p))/(1 + \exp(-(\beta_{i0} + \beta_{i1} \cdot X_p +$$

where parameters $\beta_{i0}, \beta_{i1}, \beta_{i2}, \beta_{i3}$ are intercept, effect of the matching criterion, effect of the group membership, and their mutual interaction, respectively.

The `model` argument offers several predefined models. The options are as follows: `Rasch` for 1PL model with discrimination parameter fixed on value 1 for both groups, `1PL` for 1PL model with discrimination parameter set the same for both groups, `2PL` for logistic regression model, `3PLcg` for 3PL model with fixed guessing for both groups, `3PLdg` for 3PL model with fixed inattention for both groups, `3PLc` (alternatively also `3PL`) for 3PL regression model with guessing parameter, `3PLd` for 3PL model with inattention parameter, `4PLcgdg` for 4PL model with fixed guessing and inattention parameter for both groups, `4PLcgd` (alternatively also `4PLd`) for 4PL model with fixed guessing for both groups, `4PLcdg` (alternatively also `4PLc`) for 4PL model with fixed inattention for both groups, or `4PL` for 4PL model.

Three possible parameterizations can be specified in the `"parameterization"` argument: `"irt"` returns the IRT parameters of the reference group and differences in these parameters between the reference and focal group. Parameters of asymptotes are printed separately for the reference and focal groups. `"is"` returns intercept-slope parameterization. Parameters of asymptotes are again printed separately for the reference and focal groups. `"logistic"` returns parameters in logistic regression parameterization as in the `glm` function, and it is available only for the 2PL model.

Value

A list containing elements representing items. Each element is a named numeric vector with initial values for the chosen generalized logistic regression model.

Author(s)

Adela Hladka (nee Drabinova)
Institute of Computer Science of the Czech Academy of Sciences
`<hladka@cs.cas.cz>`

Patricia Martinkova
Institute of Computer Science of the Czech Academy of Sciences
`<martinkova@cs.cas.cz>`

References

Drabinova, A. & Martinkova, P. (2017). Detection of differential item functioning with nonlinear regression: A non-IRT approach accounting for guessing. Journal of Educational Measurement, 54(4), 498–517, doi:10.1111/jedm.12158.

Hladka, A. & Martinkova, P. (2020). difNLR: Generalized logistic regression models for DIF and DDF detection. The R Journal, 12(1), 300–323, doi:10.32614/RJ2020014.

Hladka, A. (2021). Statistical models for detection of differential item functioning. Dissertation thesis. Faculty of Mathematics and Physics, Charles University.

See Also

difNLR

Examples

```
# loading data
data(GMAT)
Data <- GMAT[, 1:20] # items
group <- GMAT[, "group"] # group membership variable

# 3PL model with the same guessing for both groups
startNLR(Data, group, model = "3PLcg")
startNLR(Data, group, model = "3PLcg", parameterization = "is")
# simplified into a single table
startNLR(Data, group, model = "3PLcg", simplify = TRUE)
startNLR(Data, group, model = "3PLcg", parameterization = "is", simplify = TRUE)

# 2PL model
startNLR(Data, group, model = "2PL")
startNLR(Data, group, model = "2PL", parameterization = "is")
startNLR(Data, group, model = "2PL", parameterization = "logistic")

# 4PL model with a total score as the matching criterion
startNLR(Data, group, model = "4PL", match = "score")
startNLR(Data, group, model = "4PL", match = "score", parameterization = "is")

# starting values for model specified for each item
startNLR(Data, group,
  model = c(
    rep("1PL", 5), rep("2PL", 5),
    rep("3PL", 5), rep("4PL", 5)
  )
)

# 4PL model with fixed a and c parameters
startNLR(Data, group, model = "4PL", constraints = "ac", simplify = TRUE)
```

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