Package 'mnlfa'

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Type Package

Title Moderated Nonlinear Factor Analysis

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Description Conducts moderated nonlinear factor analysis (e.g., Curran et al., 2014, <doi:10.1080/00273171.2014.889594>).
Regularization methods are implemented for assessing non-invariant items.
Currently, the package includes dichotomous items and unidimensional
item response models. Extensions will be included in future package
versions.

Depends R (>= 3.1)

Imports CDM (>= 7.0-4), stats, utils

LinkingTo Rcpp, RcppArmadillo

Enhances aMNLFA, GPCMlasso, sirt

URL https://github.com/alexanderrobitzsch/mnlfa,
https://sites.google.com/view/alexander-robitzsch/software

License GPL (>= 2)

NeedsCompilation yes

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R topics documented:

`mnlfa-package` *Moderated Nonlinear Factor Analysis*

Description

Conducts moderated nonlinear factor analysis (e.g., Curran et al., 2014, <doi:10.1080/00273171.2014.889594>). Regularization methods are implemented for assessing non-invariant items. Currently, the package includes dichotomous items and unidimensional item response models. Extensions will be included in future package versions.

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References

Curran, P. J., McGinley, J. S., Bauer, D. J., Hussong, A. M., Burns, A., Chassin, L., Sher, K., & Zucker, R. (2014). A moderated nonlinear factor model for the development of commensurate measures in integrative data analysis. *Multivariate Behavioral Research, 49*(3), 214-231. http://dx.doi.org/10.1080/00273171.2014.889594

`data.mnlfa01` *Example Datasets for* **mnlfa** *Package*

Description

Example datasets for **mnlfa** package.

Usage

```
data(data.mnlfa01)
```

Format

- `data.mnlfa01`

  A data frame with 1000 observations for 12 items and 2 covariates.

  ```
  'data.frame': 1000 obs. of 14 variables:
  $ female: num 0.5 -0.5 0.5 -0.5 0.5 -0.5 0.5 -0.5 0.5 -0.5 ...
  $ age : num 0.79 0.36 0.22 0.79 0.22 -0.34 -0.76 -0.06 0.22 0.65 ...
  $ I1 : int 1 1 1 1 1 1 1 0 1 1 ...
  $ I2 : int 0 0 1 1 1 0 1 1 1 1 ...
  $ I3 : int 1 0 1 0 0 1 0 1 1 1 ...
  $ I4 : int 1 0 0 1 1 0 1 1 0 1 ...
  $ I5 : int 1 0 0 0 0 1 1 0 0 1 ...
  ```

```
$ I6 : int 1 0 1 1 1 0 1 0 0 1 ...
$ I7 : int 1 0 1 1 0 1 1 1 1 1 ...
$ I8 : int 0 0 1 0 1 0 1 1 1 1 ...
$ I9 : int 1 0 0 1 1 0 0 0 1 0 ...
$ I10 : int 0 0 0 0 0 0 0 0 0 1 ...
$ I11 : int 0 0 1 0 0 0 0 0 0 1 ...
$ I12 : int 0 0 0 0 0 1 1 0 1 0 ...
```

`mnlfa` *Moderated Nonlinear Factor Analysis*

Description

General function for conducting moderated nonlinear factor analysis (Curran et al., 2014). Item slopes and item intercepts can be modeled as functions of person covariates.

Parameter regularization is allowed. For categorical covariates, group lasso can be used for regularization.

Usage

```
mnlfa(dat, items, item_type="2PL", formula_int=~1, formula_slo=~1, formula_mean=~0,
  formula_sd=~0, theta=NULL, parm_list_init=NULL, parm_trait_init=NULL, prior_init=NULL,
  regular_lam=c(0, 0), regular_type=c("none", "none"), maxit=1000, msteps=4, conv=1e-05,
   conv_mstep=1e-04, h=1e-04, parms_regular_types=NULL, parms_regular_lam=NULL,
   parms_iterations=NULL, center_parms=NULL, center_max_iter=6, L_max=.07,
   verbose=TRUE)

## S3 method for class 'mnlfa'
summary(object, file=NULL, ...)
```

Arguments

`dat`	Data frame with item responses
`items`	Vector containing item names
`item_type`	String or vector of item types. Currently, only item types `"1PL"` or `"2PL"` can be chosen.
`formula_int`	String or list with formula for item intercepts
`formula_slo`	String or list with formula for item slopes
`formula_mean`	Formula for mean of the trait distribution
`formula_sd`	Formula for standard deviation of the trait distribution
`theta`	Grid of θ values used for approximation of normally distributed trait
`parm_list_init`	Optional list of initial item parameters
`parm_trait_init`	Optional list of initial parameters for trait distribution

`prior_init` Optional matrix of prior distribution for persons

`regular_lam` Vector of length two containing two general regularization parameters for item intercepts and item slopes

`regular_type` Type of regularization method. Can be `"none"`, `"lasso"`, `"scad"` or `"mcp"`.

`maxit` Maximum number of iterations

`msteps` Maximum number of M-steps

`conv` Convergence criterion with respect to parameters

`conv_mstep` Convergence criterion in M-step

`h` Numerical differentiation parameter

`parms_regular_types`
Optional list containing parameter specific regularization types

`parms_regular_lam`
Optional list containing parameter specific regularization parameters

`parms_iterations`
Optional list containing sequence of parameter indices used for updating

`center_parms` Optional list indicating which parameters should be centered during initial iterations.

`center_max_iter`
Maximum number of iterations in which parameters should be centered.

`L_max` Majorization parameter used in regularization

`verbose` Logical indicating whether output should be printed

`object` Object of class `mnlfa`

`file` Optional file name

`...` Further arguments to be passed

Details

The moderated factor analysis model for dichotomous responses defined as

$$P(X_{pi}=1|\theta_p) = invlogit(a_{pi}\theta_p - b_{pi})$$

The trait distribution $\theta_p \sim N(\mu_p, \sigma_p^2)$ allows a latent regression of person covariates on the mean with $\mu_p = \boldsymbol{X}_p\boldsymbol{\gamma}$ (to be specified in `formula_mean`) and the logarithm of the standard deviation $\log \sigma_p = \boldsymbol{Z}_p\boldsymbol{\delta}$ (to be specified in `formula_sd`). Item intercepts and item slopes can be moderated by person covariates, i.e. $a_{pi} = \boldsymbol{W}_{pi}\boldsymbol{\alpha}_i$ and $b_{pi} = \boldsymbol{V}_{pi}\boldsymbol{\beta}_i$. Regularization on (some of) the $\boldsymbol{\alpha}_i$ or $\boldsymbol{\beta}_i$ parameters is allowed.

The model is estimated using an EM algorithm with the coordinate descent method during the M-step (Sun et al., 2016).

Value

List with model results including

`item` Summary table for item parameters

`trait` Summary table for trait parameters

References

Curran, P. J., McGinley, J. S., Bauer, D. J., Hussong, A. M., Burns, A., Chassin, L., Sher, K., & Zucker, R. (2014). A moderated nonlinear factor model for the development of commensurate measures in integrative data analysis. *Multivariate Behavioral Research, 49*(3), 214-231. http://dx.doi.org/10.1080/00273171.2014.889594

Sun, J., Chen, Y., Liu, J., Ying, Z., & Xin, T. (2016). Latent variable selection for multidimensional item response theory models via L1 regularization. *Psychometrika, 81*(4), 921-939. https://doi.org/10.1007/s11336-016-9529-6

See Also

See also the **aMNLFA** package for automatized moderated nonlinear factor analysis which provides convenient wrapper functions for automized analysis in the *Mplus* software.

See the **GPCMlasso** package for the regularized generalized partial credit model.

Examples

```
#############################################################################
# EXAMPLE 1: Dichotomous data, 1PL model
#############################################################################

data(data.mnlfa01, package="mnlfa")

dat <- data.mnlfa01
# extract items from dataset
items <- grep("I[0-9]", colnames(dat), value=TRUE)
I <- length(items)

# maximum number of iterations (use only few iterations for the only purpose of
# providing CRAN checks)
maxit <- 10

#***** Model 1: 1PL model without moderating parameters and without covariates for traits

# no covariates for trait
formula_mean <- ~0
formula_sd <- ~1
# no item covariates
formula_int <- ~1
formula_slo <- ~1

mod1 <- mnlfa::mnlfa( dat=dat, items, item_type="1PL", formula_int=formula_int,
             formula_slo=formula_slo, formula_mean=formula_mean, formula_sd=formula_sd,
             maxit=maxit )
summary(mod1)


#***** Model 2: 1PL model without moderating parameters and with covariates for traits

# covariates for trait
formula_mean <- ~female + age
```

```
formula_sd <- ~1

mod2 <- mnlfa::mnlfa( dat=dat, items, item_type="1PL", formula_int=formula_int,
             formula_slo=formula_slo, formula_mean=formula_mean, formula_sd=formula_sd)
summary(mod2)

#***** Model 3: 1PL model with moderating parameters and with covariates for traits
#***   Regularization method 'mcp'

# covariates for trait
formula_mean <- ~female + age
formula_sd <- ~1
# moderation effects for items
formula_int <- ~1+female+age
formula_slo <- ~1

# center parameters for female and age in initial iterations for improving convergence
center_parms <- list( rep(2,I), rep(3,I) )

# regularization parameters for item intercept and item slope, respectively
regular_lam <- c(.06, .25)
regular_type <- c("mcp","none")

mod3 <- mnlfa::mnlfa( dat=dat, items, item_type="1PL", formula_int=formula_int,
            formula_slo=formula_slo, formula_mean=formula_mean, formula_sd=formula_sd,
         center_parms=center_parms, regular_lam=regular_lam, regular_type=regular_type )
summary(mod3)


#***** Model 4: 1PL model with selected moderated item parameters

#* trait distribution
formula_mean <- ~0+female+age
formula_sd <- ~1

#* formulas for item intercepts
formula_int <- ~1
formula_int <- mnlfa::mnlfa_expand_to_list(x=formula_int, names_list=items)
mod_items <- c(4,5,6,7)
for (ii in mod_items){
    formula_int[[ii]] <- ~1+female+age
}
formula_slo <- ~1

mod4 <- mnlfa::mnlfa( dat=dat, items, item_type="1PL", formula_int=formula_int,
              formula_slo=formula_slo, formula_mean=formula_mean, formula_sd=formula_sd)
mod4$item
mod4$trait
summary(mod4)
```

mnlfa_expand_to_list *Expands Input Into a List*

Description

Expands an input into a list.

Usage

```
mnlfa_expand_to_list(x, names_list)
```

Arguments

x	An R object
names_list	Names of the list

Value

A list

Examples

```
#############################################################################
# EXAMPLE 1: Test example
#############################################################################

formula_int <- ~1+female+age
items <- paste0("I",1:12)
formula_int <- mnlfa::mnlfa_expand_to_list(x=formula_int, names_list=items)
formula_int[[1]] <- ~0
```

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