Package ‘bifactor’

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Type Package

Title Exploratory factor and bi-factor modeling with multiple general factors

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Description Fit exploratory factor models and bi-factor models with multiple general factors.

License GPL-3

LazyData TRUE

Depends R (>= 4.0)

Imports Rcpp

URL https://github.com/Marcosjnez/bifactor

BugReports https://github.com/Marcosjnez/bifactor/issues

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NeedsCompilation yes

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R topics documented:

`asymp_cov` *Asymptotic standard errors for correlation matrices.*

Description

Get the asymptotic standard errors of correlation matrices of normal or arbitrary random deviates.

Usage

```
asymp_cov(R, X = NULL, eta = 1, type = "normal")
```

Arguments

`R`	Correlation matrix.
`X`	Optional raw data matrix.
`eta`	Skewness parameter for elliptical data distributions.
`type`	Type of random deviates: "normal", "elliptical" or "general".

Details

If `type = "normal"`, the calculation assumes that the raw data follows a multivariate normal distribution. If `type = "elliptical"`, the calculation assumes that the raw data follows an elliptical distribution with skewness parameter `eta`. If `type = "general"`, no assumption is made but need to provide the raw data via the `X` argument.

Value

The asymptotic covariance matrix of `R`.

References

M.W. Browne and A. Shapiro (1986). The asymptotic covariance matrix of sample correlation coefficients under general conditions. Linear Algebra and its Applications, 82, 169-176. https://doi.org/10.1016/0024-3795(86)90150-3

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bifactor *Fit an exploratory bi-factor model with one or multiple general factors.*

Description

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Usage

```
bifactor(X, n_generals, n_groups, method = "GSLiD", cor = "pearson",
estimator = "uls", projection = "oblq", nobs = NULL, PhiTarget = NULL,
PhiWeight = NULL, blocks = NULL, block_weights = NULL,
oblq_factors = NULL, init_Target = NULL, maxit = 20L, cutoff = 0,
normalization = "none", w = 1, random_starts = 1L, cores = 1L,
init = NULL, efa_control = NULL, rot_control = NULL, first_efa = NULL,
second_efa = NULL, verbose = TRUE)
```

Arguments

`X`	Raw data matrix or correlation matrix.
`n_generals`	Number of general factors to extract.
`n_groups`	Number of group factors to extract.
`method`	"GSLiD", "SL" (Schmid-Leiman), and "botmin" (bifactor-oblimin-target minimization). Defaults to "GSLiD".
`cor`	Correlation method. Available correlations: c("pearson", "poly"). Defaults to "pearson".
`estimator`	EFA fitting estimator: "ml" (maximum likelihood for multivariate normal variable), "uls" (minimum residuals), "pa" (principal axis) or "minrank" (minimum rank). Defaults to "uls".
`projection`	Projection method. Available projections: "orth" (orthogonal), "oblq" (oblique) and "poblq" (partially oblique). Defaults to "oblq".
`missing`	The way to handle missing data. Options: c("impute.mean", "impute.median", "complete.cases", "pairwise.complete.cases"). Defaults to "pairwise.complete.cases".
`nobs`	Sample size. Defaults to NULL.
`PhiTarget`	Target matrix for the factor correlations. Defaults to NULL.
`PhiWeight`	Weight matrix for the factor correlations. Defaults to NULL.

`blocks`	Vector with the number of factors for which separately applying the rotation criterion. Defaults to NULL.
`block_weights`	Vector of weights for each block of factors.
`oblq_factors`	Vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one block with 2 factors and another block with 4 factors. Everything else is orthogonal. Defaults to NULL.
`init_Target`	Initial target matrix for the loadings. Defaults to NULL.
`maxit`	Maximum number of iterations for the GSLiD algorithm. Defaults to 20L.
`cutoff`	Cut-off used to update the target matrix upon each iteration. Defaults to 0.
`normalization`	Available normalizations: "kaiser". Defaults to "none".
`w`	w parameter for the extended target criterion ("xtarget"). Defaults to 1L.
`random_starts`	Number of rotations with different random starting values. The rotation with the smallest cost function value is returned. Defaults to 1L.
`cores`	Number of cores for parallel execution of multiple rotations. Defaults to 1L.
`init`	Initial uniquenesses values for exploratory factor analysis estimation. Defaults to NULL.
`efa_control`	List of control parameters for efa fitting. Defaults to NULL.
`rot_control`	List of control parameters for the rotation algorithm. Defaults to NULL.
`first_efa`	List of arguments to pass to `efast` to perform the first-order solution for the Schmid-Leiman method. Defaults to NULL.
`second_efa`	List of arguments to pass to `efast` to perform the second-order solution for the Schmid-Leiman method. Defaults to NULL.
`verbose`	Print the convergence progress information. Defaults to TRUE.

Details

If `efa.control = NULL`, then `list(maxit = 1e4)` is passed to `efa.control`. If `rot_control = NULL`, then `list(maxit = 1000, eps = 1e-05)` is passed to `rot_control`, where `eps` is the absolute tolerance. When the objective function does not make a larger improvement than `eps`, the algorithm is assumed to converge.

If `Target` is provided but not `Weight`, then `Weight = 1 - Target` by default, which means a partially specified target rotation is performed. The same applies for `PhiTarget` and `PhiWeight`.

If `init = NULL`, then the squared multiple correlations of each item with the remaining ones are used as initial values (These are known to be upper bounds).

If `init_Target` is provided, then an initial target by means of the Schmid-Leiman transformation is not necessary.

If `cutoff` is not 0, loadings smaller than such a cut-off are fixed to 0. When `cutoff = 0`, an empirical cut-off is used for each column of the loading matrix. They are the mean of the one-lagged differences of the sorted squared normalized loadings. Then, the target is determined by fixing to 0 the squared normalized loadings smaller than such cut-offs.

Value

List of class `bifactor`.

`efa` List containing objects related to the exploratory factor analysis estimation. See `efast`.

`bifactor` List with the following components:

- loadings - Rotated loading matrix.
- Phi - Factor correlation matrix.
- T - Transformation matrix.
- f - Objective value at the minimum.
- iterations - Number of iterations performed by the rotation algorithm.
- convergence - Convergence of the rotation algorithm.
- uniquenesses - Vector of uniquenesses.
- Rhat - Correlation matrix predicted by the model.
- Target - Updated target matrix.
- Weight - Weight matrix. It is the complement of the updated target.
- GSLiD_iterations - Number of iterations performed by the GSLiD algorithm.
- GSLiD_convergence - Convergence of the GSLiD algorithm.
- min_congruences - Vector containing, for each iteration, the minimum Tucker's congruence between the current loading matrix and the previous loading matrix.
- max_abs_diffs - Vector containing, for each iteration, the maximum absolute difference between the current loading matrix and the previous loading matrix.

`elapsed` Total amount of time spent for execution (in nanoseconds).

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Examples

```
## Not run: # Simulate data:
sim <- sim_factor(n_generals = 3, groups_per_general = 5, items_per_group = 6,
generals_rho = 0.3)
scores <- MASS::mvrnorm(1e4, rep(0, nrow(sim$R)), Sigma = sim$R)
s <- cor(scores)

# Fit an exploratory bi-factor model with GSLiD:
fit <- bifactor(s, n_generals = 3, n_groups = 15, method = "GSLiD",
estimator = "uls", projection = "poblq", nobs = NULL, oblq_factors = 3,
random_starts = 10, cores = 8, w = 1, maxit = 20, verbose = TRUE, normalization = "none")

## End(Not run)
```

`check_deriv` *Check the derivatives and differentials of rotation criteria.*

Description

Check the derivatives and differentials of rotation criteria.

Usage

```
check_deriv(L, Phi, dL, dP, rotation = "oblimin", projection = "oblq",
Target = NULL, Weight = NULL, PhiTarget = NULL, PhiWeight = NULL,
blocks = NULL, block_weights = NULL,
oblq_factors = NULL, gamma = 0,
epsilon = 0.01, k = 0L, w = 1)
```

Arguments

`L`	Loading matrix.
`Phi`	Factor correlation matrix.
`dL`	Perturbation for L.
`dP`	Perturbation for Phi.
`rotation`	Rotation criterion. Available rotations: "varimax", "cf" (Crawford-Ferguson), "oblimin", "geomin", "target", "xtarget" (extended target) and "none". Defaults to "oblimin".
`projection`	Projection method. Available projections: "orth" (orthogonal), "oblq" (oblique), "poblq" (partially oblique). Defaults to "oblq".
`Target`	Target matrix for the loadings. Defaults to NULL.
`Weight`	Weight matrix for the loadings. Defaults to NULL.
`PhiTarget`	Target matrix for the factor correlations. Defaults to NULL.
`PhiWeight`	Weight matrix for the factor correlations. Defaults to NULL.
`blocks`	Vector with the number of factors for which separately applying the rotation criterion. Defaults to NULL.
`block_weights`	Vector of weights for each block of factors.
`oblq_factors`	Vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one block with 2 factors and another block with 4 factors. Everything else is orthogonal. Defaults to NULL.
`gamma`	γ parameter for the oblimin criterion. Defaults to 0 (quartimin).
`epsilon`	ϵ parameter for the geomin criterion. Defaults to 0.01.
`k`	k parameter for the Crawford-Ferguson family of rotation criteria. Defaults to 0.
`w`	w parameter for the extended target criterion ("xtarget"). Defaults to 1L.

Details

None yet.

Value

A list with the objective value and the gradients and differentials of L and Phi.

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efast *Fast exploratory factor analysis.*

Description

Fast exploratory factor analysis.

Usage

```
efast(X, nfactors, cor = "pearson", estimator = "uls",
rotation = "oblimin", projection = "oblq", nobs = NULL,
Target = NULL, Weight = NULL, PhiTarget = NULL, PhiWeight = NULL,
blocks = NULL, block_weights = NULL,
oblq_factors = NULL, gamma = 0,
epsilon = 1e-02, k = 0, w = 1,
random_starts = 1L, cores = 1L,
init = NULL, efa_control = NULL, rot_control = NULL)
```

Arguments

`X`	Raw data matrix or correlation matrix.
`nfactors`	Number of common factors to extract.
`cor`	Correlation method. Available correlations: c("pearson", "poly"). Defaults to "pearson".
`estimator`	EFA fitting estimator: "ml" (maximum likelihood for multivariate normal variables), "uls" (minimum residuals), "pa" (principal axis) and "minrank" (minimum rank). Defaults to "uls".
`rotation`	Rotation criterion. Available rotations: "varimax", "cf" (Crawford-Ferguson), "oblimin", "geomin", "target", "xtarget" (extended target) and "none". Defaults to "oblimin".
`projection`	Projection method. Available projections: "orth" (orthogonal), "oblq" (oblique), "poblq" (partially oblique). Defaults to "oblq".
`missing`	The way to handle missing data. Options: c("impute.mean", "impute.median", "complete.cases", "pairwise.complete.cases"). Defaults to "pairwise.complete.cases".
`nobs`	Sample size. Defaults to NULL.
`Target`	Target matrix for the loadings. Defaults to NULL.
`Weight`	Weight matrix for the loadings. Defaults to NULL.

PhiTarget	Target matrix for the factor correlations. Defaults to NULL.
PhiWeight	Weight matrix for the factor correlations. Defaults to NULL.
blocks	List of vectors with the indexes of the factors for which separately applying the rotation criterion. Defaults to NULL.
block_weights	Vector of weights for each block of factors.
oblq_factors	Vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one block with 2 factors and another block with 4 factors. Everything else is orthogonal. Defaults to NULL.
gamma	γ parameter for the oblimin criterion. Defaults to 0 (quartimin).
epsilon	ϵ parameter for the geomin criterion. Defaults to 0.01.
k	k parameter for the Crawford-Ferguson family of rotation criteria. Defaults to 0.
w	w parameter for the extended target criterion ("xtarget"). Defaults to 1L.
random_starts	Number of rotations with different random starting values. The rotation with the smallest cost function value is returned. Defaults to 1L.
cores	Number of cores for parallel execution of random starts. Defaults to 1L.
init	Initial uniquenesses values for exploratory factor analysis estimation. Defaults to NULL.
efa_control	List of control parameters for efa fitting. Defaults to NULL.
rot_control	List of control parameters for the rotation algorithm. Defaults to NULL.

Details

If efa.control = NULL, then list(maxit = 1e4) is passed to efa.control. If rot_control = NULL, then list(maxit = 1000, eps = 1e-05) is passed to rot_control, where eps is the absolute tolerance. When the objective function does not make a larger improvement than eps, the algorithm is assumed to converge.

If Target is provided but not Weight, then Weight = 1 - Target by default, which means a partially specified target rotation is performed. The same applies for PhiTarget and PhiWeight.

If init = NULL, then the squared multiple correlations of each item with the remaining ones are used as initial values (These are known to be upper bounds).

If a Heywood case is encountered, then estimator = "minrank" is automatically applied to ensure positive uniquenesses.

Value

List of class efast with the following components:

efa List containing the following objects:

- loadings - Unrotated loadings.
- uniquenesses - Vector of uniquenesses.
- Rhat - Correlation matrix predicted by the model.
- residuals - Residual correlation matrix.

- f - Objective value at the minimum.
- Heywood - TRUE if any Heywood case is encountered and FALSE otherwise.
- iterations - Number of iterations for the L-BFGS-B algorithm to converge.
- convergence - TRUE if the L-BFGS-B algorithm converged and FALSE otherwise.
- estimator - Method used to fit the exploratory factor analysis.

`rotation` List of class `rotation`. Only if the argument `rotation` is not "none". See `rotate` for the components.

`elapsed` Total amount spent for execution (in nanoseconds).

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Examples

```
## Not run:
# Simulate data:
sim <- sim_factor(n_generals = 0, groups_per_general = 5, items_per_group = 6)
scores <- MASS::mvrnorm(1e3, rep(0, nrow(sim$R)), Sigma = sim$R)
s <- cor(scores)

# Fit efa:
fit <- efast(s, nfactors = 5, estimator = "uls", rotation = "oblimin",
projection = "oblq", gamma = 0, random_starts = 10L, cores = 1L)

## End(Not run)
```

`fit` *Compute fit measures for exploratory factor models.*

Description

Compute fit measures for exploratory factor models.

Usage

```
fit(model, nobs = NULL)
```

Arguments

`nobs` Sample size. Defaults to NULL.

`model` Object of class efa or cfa.

Details

`fit`... to be explained

Value

Vector of fit measures.

Author(s)

Vithor R. Franco & Marcos Jiménez

`fscores` *Compute factor scores*

Description

Compute the factor scores from an exploratory factor model

Usage

```
fscores(fit, scores = NULL, method = "regression")
```

Arguments

`fit`	object of class ‘efa‘ or ‘bifactor‘.
`scores`	Matrix of raw scores.
`method`	Method to compute the factor scores.

Details

...

Value

List...

Author(s)

Marcos Jiménez & Vithor R. Franco

`get_target` *Get a target from a loading matrix.*

Description

Get a target for the loading matrix using a custom or empirical cut-off.

Usage

```
get_target(loadings, Phi = NULL, cutoff = 0)
```

Arguments

`loadings`	A matrix of loadings.
`Phi`	A correlation matrix among the factors. Defaults to NULL.
`cutoff`	The cut-off used to create the target matrix. Defaults to 0.

Details

If `cutoff` is not 0, loadings smaller than such a cut-off are fixed to 0. When `cutoff = 0`, an empirical cut-off is used for each column of the loading matrix. They are the mean of the one-lagged differences of the sorted squared normalized loadings. Then, the target is determined by fixing to 0 the squared normalized loadings smaller than such cut-offs.

Value

A target matrix.

References

Garcia-Garzon, E., Abad, F. J., & Garrido, L. E. (2019). Improving bi-factor exploratory modeling: Empirical target rotation based on loading differences. Methodology: European Journal of Research Methods for the Behavioral and Social Sciences, 15(2), 45–55. https://doi.org/10.1027/1614-2241/a000163

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

parallel — *Hierarchical parallel analysis using either principal components (PCA) or principal axis factoring (PAF).*

Description

Perform hierarchical parallel analysis to detect dimensionality using either principal components or principal axis factoring.

Usage

```
parallel(X, nboot = 100L, cor = "pearson", quant = NULL, mean = TRUE, replace = FALSE,
PA = NULL, hierarchical = FALSE, efa = NULL, cores = 1L)
```

Arguments

`X`	Raw data matrix.
`nboot`	Number of bootstrap samples.
`missing`	The way to handle missing data. Options: c("impute.mean", "impute.median", "complete.cases", "pairwise.complete.cases"). Defaults to "pairwise.complete.cases".
`quant`	Vector of quantiles of the distribution of bootstrap eigenvalues to which the compare the sample eigenvalues.
`mean`	Logical. Compare the sample eigenvalues to the mean of the bootstrap eigenvalues. Defaults to TRUE.
`replace`	Logical indicating whether the columns of `X` should be permuted with replacement.
`PA`	Parallel analysis method. It can be either principal components ("PCA"), principal axis ("PAF") or both ("PCA" and "PAF"). Defaults to NULL, which sets c("PCA", "PAF").
`hierarchical`	Logical indicating whether a second parallel analysis should be performed from the factor scores obtained after a first factor analysis analysis.
`efa`	A list of arguments to pass to `efast` when `hierarchical = TRUE`.
`cores`	Number of cores to perform the parallel bootstrapping.
`type`	Type of correlations: "pearson" or "poly".

Details

Not yet.

Value

A list with the bootstrapped eigenvalues and the estimated dimensionality.

References

Horn, J. L. (1965). A Rationale and Test For the Number of Factors in Factor Analysis, Psychometrika, 30, 179-85. https://doi.org/10.1007/BF02289447

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polyfast — *Fast polychoric correlations.*

Description

Compute huge polychoric correlation matrices very fast.

Usage

```
polyfast(X, acov = "none", smooth = "pd", min_eigval = 0.001, nboot = 1000L, fit = FALSE, cores = 1L)
```

Arguments

`X`	Matrix of categorical scores. The lowest score must start at 0.
`missing`	The way to handle missing data. Options: c("impute.mean", "impute.median", "complete.cases", "pairwise.complete.cases"). Defaults to "pairwise.complete.cases".
`acov`	Use acov = 'cov' to obtain the asymptotic covariance matrix and acov = 'var' to simply obtain the asymptotic variances. Use "bootstrap" for estimating the asymptotic covariance matrix by resampling. Defaults to "none".
`smooth`	Smooth the matrix to be positive definite ("pd"), positive semi-definite ("psd"), or estimate the maximum likely polychoric correlation matrix under the positive semi-definite constraint ("analytical"). Defaults to "none".
`min_eigval`	Minimum eigenvalue when smooth = "pd". Defaults to 0.001.
`nboot`	Number of bootstrap samples to compute the standard errors. It only works if acov = "bootstrap". Defaults to 1000L.
`fit`	Should the fit value be calculated? Defaults to FALSE.
`cores`	Number of parallel cores to compute the polychoric correlations.

Details

None yet.

Value

A list with the polychoric correlations, the thresholds, and the elapsed time in nanoseconds.

prints *S3Methods for Printing*

Description

Prints for `bifactor` objects

Usage

```
## S3 method for class 'efa'
print(x, nobs=NULL, ...)

## S3 method for class 'bifactor'
print(x, nobs=NULL, ...)
```

Arguments

`x`	Object from `bifactor` package.
`nobs`	Optional number of observations. If not provided, Chi-squared-based statistics will not be computed.
`...`	Additional arguments

Value

Prints `bifactor` object

Author(s)

Marcos Jimenez <marcosjnezhquez@gmail.com> and Víthor R. Franco <vithorfranco@gmail.com>

random_oblq *Generate random oblique matrices.*

Description

Generate random oblique matrices from a standard normal distribution.

Usage

```
random_oblq(p, q)
```

Arguments

`p`	Number of rows.
`q`	Number of columns. Should not be greater than p.

Value

An oblique matrix with normally distributed data.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

`random_orth` *Generate random orthogonal matrices.*

Description

Generate random orthogonal matrices from a standard normal distribution. First, a matrix of random standard normal variables is simulated and then, the Q factor from the QR decomposition is returned.

Usage

```
random_orth(p, q)
```

Arguments

`p`	Number of rows.
`q`	Number of columns. Should not be greater than p.

Value

An orthogonal matrix with normally distributed data.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

random_poblq *Generate a random partially oblique matrix.*

Description

First, a matrix is simulated from a standard normal distribution. Second,the matrix is normalized and the Gram-Schmidt process is performed between the oblique blocks. Finally, the orthogonal blocks correspond to those columns of the Q matrix from the QR decomposition.

Usage

```
random_poblq(p, q, oblq_factors)
```

Arguments

`p`	Number of rows.
`q`	Number of columns. Should not be greater than p.
`oblq_factors`	A vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one with 2 factors and another with 4 factors. Everything else is orthogonal.

Value

A partially oblique matrix.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Examples

```
random_poblq(p = 7, q = 7, oblq_factors = c(3, 2))
```

retr_oblq *Retraction of a matrix onto the oblique manifold.*

Description

Transform a matrix into an oblique matrix.

Usage

```
retr_oblq(X)
```

Arguments

`X`	A matrix.

Value

An oblique matrix.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

`retr_orth` *Retraction of a matrix onto the orthogonal manifold.*

Description

Transform a matrix into an orthogonal matrix.

Usage

```
retr_orth(X)
```

Arguments

`X`	A matrix.

Value

An orthogonal matrix.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

retr_poblq — *Retraction of a matrix onto the partially oblique manifold.*

Description

Transform a matrix into a partially oblique matrix.

Usage

```
retr_poblq(X, oblq_factors)
```

Arguments

X	A matrix.
oblq_factors	A vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one with 2 factors and another with 4 factors. Everything else is orthogonal.

Value

A partially oblique matrix.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Examples

```
X <- replicate(8, rnorm(8))
retr_poblq(X, c(2, 3, 3))
```

rotate — *Fast rotation algorithm for factor analysis.*

Description

Riemannian Newton Trust-Region algorithm to quickly perform (parallel) rotations with different random starting values.

Usage

```
rotate(loadings, rotation = "oblimin", projection = "oblq",
gamma = 0, epsilon = 0.01, k = 0, w = 1,
Target = NULL, Weight = NULL, PhiTarget = NULL, PhiWeight = NULL,
blocks = NULL, block_weights = NULL, oblq_factors = NULL,
normalization = "none",
rot_control = NULL, random_starts = 1L, cores = 1L)
```

Arguments

`loadings`	Unrotated loading matrix.
`rotation`	Rotation criterion. Available rotations: "varimax", "cf" (Crawford-Ferguson), "oblimin", "geomin", "target", "xtarget" (extended target) and "none". Defaults to "oblimin".
`projection`	Projection method. Available projections: "orth" (orthogonal), "oblq" (oblique), "poblq" (partially oblique). Defaults to "oblq".
`gamma`	γ parameter for the oblimin criterion. Defaults to 0 (quartimin).
`epsilon`	ϵ parameter for the geomin criterion. Defaults to 0.01.
`k`	k parameter for the Crawford-Ferguson family of rotation criteria. Defaults to 0.
`w`	w parameter for the extended target criterion ("xtarget"). Defaults to 1.
`Target`	Target matrix for the loadings. Defaults to NULL.
`Weight`	Weight matrix for the loadings. Defaults to NULL.
`PhiTarget`	Target matrix for the factor correlations. Defaults to NULL.
`PhiWeight`	Weight matrix for the factor correlations. Defaults to NULL.
`blocks`	Vector with the number of factors for which separately applying the rotation criterion. Defaults to NULL.
`block_weights`	Vector of weights for each block of factors.
`oblq_factors`	Vector with the number of factors for each oblique block. E.g.: c(2, 4) means that there are two blocks of oblique factors: one block with 2 factors and another block with 4 factors. Everything else is orthogonal. Defaults to NULL.
`normalization`	Available normalizations: "kaiser". Defaults to "none".
`rot_control`	List of control parameters for the rotation algorithm. Defaults to NULL.
`random_starts`	Number of rotations with different random starting values. The rotation with the smallest cost function value is returned. Defaults to 1L.
`cores`	Number of cores for parallel execution of random starts. Defaults to 1L.

Details

If `rot_control = NULL`, then `list(maxit = 1000, eps = 1e-05)` is passed to `rot_control`, where eps is the absolute tolerance. When the objective function does not make a larger improvement than eps, the algorithm is assumed to converge. If `Target` is provided but not `Weight`, then `Weight = 1 - Target` by default, which means a partially specified target rotation is performed. The same applies for `PhiTarget` and `PhiWeight`.

Value

List of class `rotation` with the following components:

`loadings`	Rotated loading matrix.
`Phi`	Correlation matrix among the factors.
`T`	Rotation matrix.
`f`	Objective value at the minimum.
`iterations`	Number of iterations for the rotation algorithm to converge.
`convergence`	TRUE if the algorithm converged and FALSE otherwise.
`elapsed`	Total amount of time spent for execution (in nanoseconds).

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Zhang, G., Hattori, M., Trichtinger, L. A., & Wang, X. (2019). Target rotation with both factor loadings and factor correlations. Psychological Methods, 24(3), 390–402. https://doi.org/10.1037/met0000198

`se` *Standard errors for rotated factor loadings, factor correlations and uniquenesses.*

Description

Compute the sandwich standard errors of factor loadings, factor correlations and uniquenesses.

Usage

```
se(fit = NULL, n = NULL, X = NULL, type = "normal", eta = 1)
```

Arguments

`fit`	Optional `efast` model.
`X`	Raw data matrix.
`type`	Type of random deviates: "normal", "elliptical" or "general".
`eta`	Skewness parameter for elliptical data distributions.
`n`	Sample size.

Details

Currently, only available for `estimator` = `uls`.

Value

A list with the standard errors of the rotated factor loadings, factor correlations and uniquenesses.

References

Zhang G, Preacher KJ, Hattori M, Jiang G, Trichtinger LA (2019). A sandwich standard error estimator for exploratory factor analysis with nonnormal data and imperfect models. Applied Psychological Measurement, 43, 360–373. https://doi.org/10.1177/0146621618798669

`sim_factor` *Simulate a bi-factor structure with either one or multiple general factors.*

Description

Simulate bifactor structures with multiple general factors, cross-loadings, pure items, correlated factors, and more.

Usage

```
sim_factor(n_generals = 0, groups_per_general = 5,
items_per_group = 6,
loadings_g = "medium", loadings_s = "medium",
crossloadings = 0, pure = FALSE,
generals_rho = 0, groups_rho = 0,
method = "minres", fit = "rmsr", misfit = 0,
error_method = "cudeck", efa = FALSE,
lambda = NULL, Phi = NULL, Psi = NULL)
```

Arguments

`n_generals` Number of general factors.

`groups_per_general`
Number of group factors per general factor.

`items_per_group`
Number of items per group factor.

`loadings_g` Loadings' magnitude on the general factors: "low", "medium" or "high". Defaults to "medium".

`loadings_s` Loadings' magnitude on the group factors: "low", "medium" or "high". Defaults to "medium".

`crossloadings` Magnitude of the cross-loadings among the group factors. Defaults to 0.

`pure` Fix a pure item on each general factor. Defaults to FALSE.

`generals_rho` Correlation among the general factors. Defaults to 0.

`groups_rho` Correlation among the group factors. Defaults to 0.

`method`	Method used to generate population error: "minres" or "ml".
`fit`	Fit index to control the population error.
`misfit`	Misfit value to generate population error.
`error_method`	Method used to control population error: c("yuan", "cudeck"). Defaults to "cudeck".
`efa`	Reproduce the error with EFA or CFA. Defaults to FALSE (CFA).
`lambda`	Custom loading matrix. If Phi is NULL, then all the factors will be correlated at the value given in groups_rho.
`Phi`	Custom Phi matrix. If lambda is NULL, then Phi should be conformable to the loading matrix specified with the above arguments.
`Psi`	Custom Psi matrix.

Details

`sim_factor` generates bi-factor and generalized bifactor patterns with cross-loadings, pure items and correlations among the general and group factors. When `crossloading` is different than 0, one cross-loading is introduced for an item pertaining to each group factor. When `pure` is TRUE, one item loading of each group factor is removed so that the item loads entirely on the general factor. To maintain the item communalities constant upon these modifications, the item loading on the other factors may shrunk (if adding cross-loadings) or increase (if setting pure items).

Loading magnitudes may range between 0.3-0.5 ("low"), 0.4-0.6 ("medium") and 0.5-0.7 ("high").

Value

List with the following objects:

`lambda`	Population loading matrix.
`Phi`	Population factor correlation matrix.
`R`	Population correlation matrix.
`R_error`	Population correlation matrix with error.
`uniquenesses`	Vector of population uniquenesses.
`delta`	Minimum of the objective function that correspond to the misfit value.

References

Jiménez, M., Abad, F.J., Garcia-Garzon, E., Garrido, L.E. (2021, June 24). Exploratory bi-factor analysis with multiple general factors. Under review. Retrieved from https://osf.io/7aszj/?view_only=8f7bd98025104347a96f

sl *Schmid-Leiman Transformation.*

Description

Schmid-Leiman transformation into a bi-factor pattern with one or multiple general factors.

Usage

```
sl(X, n_generals, n_groups, cor = "pearson", estimator = "uls", nobs = NULL,
first_efa = NULL, second_efa = NULL, cores = 1L)
```

Arguments

`X`	Raw data matrix or correlation matrix.
`n_generals`	Number of general factors.
`n_groups`	Number of group factors.
`cor`	Correlation method. Available correlations: c("pearson", "poly"). Defaults to "pearson".
`estimator`	EFA fitting estimator: "ml" (maximum likelihood for multivariate normal variables), "uls" (minimum residuals), "pa" (principal axis) and "minrank" (minimum rank). Defaults to "uls".
`missing`	The way to handle missing data. Options: c("impute.mean", "impute.median", "complete.cases", "pairwise.complete.cases"). Defaults to "pairwise.complete.cases".
`nobs`	Sample size. Defaults to NULL.
`first_efa`	Arguments to pass to `efast` in the first-order factor extraction. See `efast` for the default arguments.
`second_efa`	Arguments to pass to `efast` in the second-order factor extraction. See `efast` for the default arguments.
`cores`	Number of cores for the polychorics estimation.

Details

First, a hierarchical factor model is fitted using a second-order factor analysis on the factor correlation obtained from a first-order factor analysis. Then, the item loadings on the general factors are assumed to be the direct effects of the general factors according to such hierarchical model. On the other hand, the item loadings on the group factors become the originally first-order loadings post-multiplied by the diagonal matrix containing the root of the item uniquenesses.

Obviously, the first-order factor analysis should be oblique to perform a second exploratory factor analysis.

If the second-order solution does not use an orthogonal projection, then the correlation matrix among the general factors for the Schmid-Leiman solution is simply that obtained from such second-order solution.

Value

`loadings` Loading matrix of the Schmid-Leiman solution.

`first_order_solution`
Object of class `efast` with the first-order solution.

`second_order_solution`
Object of class `efast` with the second-order solution.

`uniquenesses` Vector of uniquenesses.

`Rhat` Correlation matrix predicted by the (hierarchical) model.

References

Jiménez, M., Abad, F. J., Garcia-Garzon, E., & Garrido, L. E. (2023). Exploratory Bi-factor Analysis with Multiple General Factors. Multivariate behavioral research, 1–18. Advance online publication. https://doi.org/10.1080/00273171.2023.2189571

Examples

```
## Not run:
# Simulate data:
sim <- sim_factor(n_generals = 2, groups_per_general = 3, items_per_group = 5)
lambda <- sim$lambda
Target <- ifelse(lambda > 0, 1, 0)

# Target rotation for the first-order efa and oblimin for the second-order efa:
first <- list(rotation = "target", projection = "oblq", Target = Target[, -c(1:2)])
second <- list(rotation = "oblimin", projection = "oblq", gamma = 0)

SL <- <- sl(sim$R, n_generals = 2, n_groups = 6, nobs = 100,
         first_efa = first, second_efa = second)

## End(Not run)
```

`summarys` *S3Methods for summarying*

Description

summarys for `bifactor` objects

Usage

```
## S3 method for class 'efa'
summary(object, nobs=NULL, suppress=0, order=FALSE, digits=2, ...)

## S3 method for class 'bifactor'
summary(object, nobs=NULL, suppress=0, order=FALSE, digits=2, ...)
```

Arguments

object	Object from bifactor package.
nobs	Optional number of observations. If not provided, Chi-squared-based statistics will not be computed.
suppress	Hide the loadings which absolute magnitudes are smaller than this cutoff. Defaults to 0.
order	Order the columns of the pattern matrix according to the variance they account for. Defaults to FALSE.
digits	Number of digits to display in the loading and factor correlation matrices.
...	Arguments to be passed to or from other methods.

Value

summarys bifactor object

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