Package 'nda'

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Type Package

Title Generalized Network-Based Dimensionality Reduction and Analysis

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Description Non-parametric dimensionality reduction function. Reduction with and without feature selection. Plot functions. Automated feature selections. Kosztyan et. al. (2024) <doi:10.1016/j.eswa.2023.121779>.

License GPL (>= 2)

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Depends R (>= 4.00)

Imports energy, psych, stats, igraph, Matrix, methods, Rfast, MASS, ppcor, leidenAlg, visNetwork

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Contents

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nda-package *Package of Generalized Network-based Dimensionality Reduction and Analyses*

Description

The package of Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

Author(s)

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References

Kosztyan, Z. T., Kurbucz, M. T., & Katona, A. I. (2022). Network-based dimensionality reduction of high-dimensional, low-sample-size datasets. Knowledge-Based Systems, 109180.

Kosztyán, Z. T., Katona, A. I., Kurbucz, M. T., & Lantos, Z. (2024). Generalized network-based dimensionality analysis. Expert Systems with Applications, 238, 121779. <URL: https://doi.org/10.1016/j.eswa.2023.121779>

See Also

`ndr`, `plot`, `biplot`, `summary`, `dCor`.

`biplot.nda` *Biplot function for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)*

Description

Biplot function for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Usage

```
## S3 method for class 'nda'
biplot(x, main=NULL,...)
```

Arguments

`x`	an object of class 'NDA'.
`main`	main title of biplot.
`...`	other graphical parameters.

Author(s)

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References

Kosztyán, Z. T., Katona, A. I., Kurbucz, M. T., & Lantos, Z. (2024). Generalized network-based dimensionality analysis. Expert Systems with Applications, 238, 121779. <URL: https://doi.org/10.1016/j.eswa.2023.121779>

See Also

`plot`, `summary`, `ndr`, `data_gen`.

Examples

```
# Biplot function without feature selection

# Generate 200 x 50 random block matrix with 3 blocks and lambda=0 parameter

df<-data_gen(200,50,3,0)
p<-ndr(df)
biplot(p)
```

COVID19_2020 *Covid'19 case datesets of countries (2020), where the data frame has 138 observations of 18 variables.*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Covid'19 of countries (2020), where the data frame has 138 observations of 18 variables.

Usage

```
data("COVID19_2020")
```

Format

A data frame with 138 observations 18 variables.

Source

Kurbucz, M. T. (2020). A joint dataset of official COVID-19 reports and the governance, trade and competitiveness indicators of World Bank group platforms. Data in brief, 31, 105881.

Examples

```
data(COVID19_2020)
```

CrimesUSA1990.X *Crimes in USA cities in 1990. Independent variables (X)*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Crimes in USA cities in 1990. Independent variables (X)

Usage

```
data("CrimesUSA1990.X")
```

Format

A data frame with 1994 observations 123 variables.

Source

UCI - Machine Learning Repository: https://archive.ics.uci.edu/ml/datasets/communities+and+crime

Examples

```
data(CrimesUSA1990.X)
```

`CrimesUSA1990.Y` *Crimes in USA cities in 1990. Dependent variable (Y)*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Crimes in USA cities in 1990. Dependent variable (Y)

Usage

```
data("CrimesUSA1990.Y")
```

Format

A data frame with 1994 observations 1 variables.

Source

UCI - Machine Learning Repository: https://archive.ics.uci.edu/ml/datasets/communities+and+crime

Examples

```
data(CrimesUSA1990.Y)
```

`CWTS_2020` *CWTS Leiden's University Ranking 2020 for all scientific fields, within the period of 2016-2019. 1176 observations (i.e., universities), and 42 variables (i.e., indicators).*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

CWTS Leiden's 2020 dataset, where the data frame has 1176 observations of 42 variables.

Usage

```
data("CWTS_2020")
```

Format

A data frame with 1176 observations of 42 variables.

Source

CWTS Leiden Ranking 2020: https://www.leidenranking.com/ranking/2020/list

Examples

```
data(CWTS_2020)
```

`data_gen` *Generate random block matrix for GNDA*

Description

Generate random block matrix for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Usage

```
data_gen(n,m,nfactors=2,lambda=1)
```

Arguments

`n`	number of rows
`m`	number of columns
`nfactors`	number of blocks (factors, where the default value is 2)
`lambda`	exponential smoothing, where the default value is 1

Details

`n`, `m`, `nfactors` must beintegers, and they are not less than 1; lambda should be a positive real number.

Value

`M`	a dataframe of a block matrix

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Examples

```
# Specification 30 by 10 random block matrices with 2 blocks/factors
df<-data_gen(30,10)
library(psych)
scree(df)
biplot(ndr(df))
# Specification 40 by 20 random block matrices with 3 blocks/factors
df<-data_gen(40,20,3)
library(psych)
scree(df)
biplot(ndr(df))
plot(ndr(df))

# Specification 50 by 20 random block matrices with 4 blocks/factors
# lambda=0.1
df<-data_gen(50,15,4,0.1)
scree(df)
biplot(ndr(df))
plot(ndr(df))
```

---

dCor *Calculating distance correlation of two vectors or columns of a matrix*

Description

Calculating distance correlation of two vectors or columns of a matrix for Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

The calculation is very slow for large matrices!

Usage

```
dCor(x,y=NULL)
```

Arguments

x	a numeric vector, matrix or data frame.
y	NULL (default) or a vector, matrix or data frame with compatible dimensions to x. The default is equivalent to y = x (but more efficient).

Details

If x is a numeric vector, y must be specified. If x is a numeric matrix or numeric data frame, y will be neglected.

Value

Either a distance correlation coefficient of vectors x and y, or a distance correlation matrix of x if x is a matrix or a dataframe.

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References

Rizzo M, Szekely G (2021). _energy: E-Statistics: Multivariate Inference via the Energy of Data_. R package version 1.7-8, <URL: https://CRAN.R-project.org/package=energy>.

Examples

```
# Specification of distance correlation value of vectors x and y.
x<-rnorm(36)
y<-rnorm(36)
dCor(x,y)
# Specification of distance correlaction matrix.
x<-matrix(rnorm(36),nrow=6)
dCor(x)
```

`dCov` *Calculating distance covariance of two vectors or columns of a matrix*

Description

Calculating distance covariance of two vectors or columns of a matrix for Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

The calculation is very slow for large matrices!

Usage

```
dCov(x,y=NULL)
```

Arguments

`x`	a numeric vector, matrix or data frame.
`y`	NULL (default) or a vector, matrix or data frame with compatible dimensions to x. The default is equivalent to y = x (but more efficient).

Details

If `x` is a numeric vector, `y` must be specified. If `x` is a numeric matrix or numeric data frame, `y` will be neglected.

Value

Either a distance covariance value of vectors `x` and `y`, or a distance covariance matrix of `x` if `x` is a matrix or a dataframe.

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References

Rizzo M, Szekely G (2021). _energy: E-Statistics: Multivariate Inference via the Energy of Data_. R package version 1.7-8, <URL: https://CRAN.R-project.org/package=energy>.

Examples

```
# Specification of distance covariance value of vectors x and y.
x<-rnorm(36)
y<-rnorm(36)
dCov(x,y)
# Specification of distance covariance matrix.
x<-matrix(rnorm(36),nrow=6)
dCov(x)
```

`fs.dimred` *Feature selection for PCA, FA, and (G)NDA*

Description

This function drops variables that have low communality values and/or are common indicators (i.e., correlates more than one latent variables).

Usage

```
fs.dimred(fn,DF,min_comm=0.25,com_comm=0.25)
```

Arguments

`fn`	It is a list variable of the output of a principal (PCA), a fa (FA), or an ndr (NDA) function.
`DF`	Numeric data frame, or a numeric matrix of the data table
`min_comm`	Scalar between 0 to 1. Minimal communality value, which a variable has to be achieved. The default value is 0.25.
`com_comm`	Scalar between 0 to 1. The minimal difference value between loadings. The default value is 0.25.

Details

This function only works with principal, and fa, and ndr functions.

This function drops each variable that has a low communality value (under min_comm value). In other words, that variable does not fit enough of any latent variable.

This function also drops so-called common indicators, which correlate highly with more than one latent variable. And the difference in the correlation is either lower than the com_comm value or the greatest absolute factor loading value is not twice greater than the second greatest factor loading.

Value

`dropped_low`	Numeric data frame or numeric matrix. Set of indicators (i.e. variables), which are dropped by their low communalities. This value is NULL if a correlation matrix is used as an input or there is no dropped indicator.
`dropped_com`	Numeric data frame or numeric matrix. Set of dropped common indicators (i.e. common variables). This value is NULL if a correlation matrix is used as an input or there is no dropped indicator.
`remain_DF`	Numeric data frame or numeric matrix. Set of retained indicators
`...`	Other outputs came from

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References

Abonyi, J., Czvetkó, T., Kosztyán, Z. T., & Héberger, K. (2022). Factor analysis, sparse PCA, and Sum of Ranking Differences-based improvements of the Promethee-GAIA multicriteria decision support technique. Plos one, 17(2), e0264277. doi:10.1371/journal.pone.0264277

See Also

`psych::principal`, `psych::fa`, `ndr`.

Examples

```
data<-I40_2020

library(psych)

# Principal Component Analysis (PCA)

pca<-principal(data,nfactors=2,covar=TRUE)
pca

# Feature selection with default values

PCA<-fs.dimred(pca,data)
```

```
PCA

# List of dropped, low communality value indicators
print(colnames(PCA$dropped_low))

# List of dropped, common communality value indicators
print(colnames(PCA$dropped_com))

# List of retained indicators
print(colnames(PCA$retained_DF))


# Principal Component Analysis (PCA) of correlation matrix

pca<-principal(cor(data,method="spearman"),nfactors=2,covar=TRUE)
pca

# Feature selection
min_comm<-0.25 # Minimal communality value
com_comm<-0.20 # Minimal common communality value

PCA<-fs.dimred(pca,cor(data,method="spearman"),min_comm,com_comm)
PCA
```

`fs.KMO` *Feature selection for KMO*

Description

Drop variables if their MSA_i valus is lower than a threshold, in order to increase the overall KMO (MSA) value.

Usage

```
fs.KMO(data,min_MSA=0.5,cor.mtx=FALSE)
```

Arguments

`data`	A numeric data frame
`min_MSA`	A numeric value. Minimal MSA value for variable i
`cor.mtx`	Boolean value. The input is either a correlation matrix (cor.mtx=TRUE), or not (cor.mtx=FALSE)

Details

Low Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy does not suggest using principal component or factor analysis. Therefore, this function drop variables with low KMO/MSA values.

Value

`data` Cleaned data or the cleaned correlation matrix.

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References

Abonyi, J., Czvetkó, T., Kosztyán, Z. T., & Héberger, K. (2022). Factor analysis, sparse PCA, and Sum of Ranking Differences-based improvements of the Promethee-GAIA multicriteria decision support technique. Plos one, 17(2), e0264277. doi:10.1371/journal.pone.0264277

See Also

`summary`.

Examples

```
library(psych)
data(I40_2020)
data<-I40_2020
KMO(fs.KMO(data,min_MSA=0.7,cor.mtx=FALSE))
```

GOVDB2020 *Governmental and economic data of countries (2020), where the data frame has 138 observations of 2161 variables.*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Governmental and economic data of countries (2020), where the data frame has 138 observations of 2161 variables.

Usage

```
data("GOVDB2020")
```

Format

A data frame with 138 observations of 2161 variables.

Source

Kurbucz, M. T. (2020). A joint dataset of official COVID-19 reports and the governance, trade and competitiveness indicators of World Bank group platforms. Data in brief, 31, 105881.

Examples

```
data(GOVDB2020)
```

I40_2020 *NUTS2 regional development data (2020) of I4.0 readiness, where the data frame has 414 observations of 101 variables.*

Description

Sample datasets for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

NUTS2 regional development data (2020), where the data frame has 414 observations of 101 variables.

Usage

```
data("COVID19_2020")
```

Format

A data frame with 414 observations of 101 variables.

Source

Honti, G., Czvetkó, T., & Abonyi, J. (2020). Data describing the regional Industry 4.0 readiness index. Data in Brief, 33, 106464.

Examples

```
data(I40_2020)
```

---

ndr *Genearlized Network-based Dimensionality Reduction and Analysis (GNDA)*

Description

The main function of Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

Usage

```
ndr(r,covar=FALSE,cor_method=1,cor_type=1,min_R=0,min_comm=2,Gamma=1,null_modell_type=4,
mod_mode=6,min_evalue=0,min_communality=0,com_communalities=0,use_rotation=FALSE,
rotation="oblimin")
```

Arguments

r	A numeric data frame
covar	If this value is FALSE (default), it finds the correlation matrix from the raw data. If this value is TRUE, it uses the matrix r as a correlation/similarity matrix.
cor_method	Correlation method (optional). '1' Pearson's correlation (default), '2' Spearman's correlation, '3' Kendall's correlation, '4' Distance correlation
cor_type	Correlation type (optional). '1' Bivariate correlation (default), '2' partial correlation, '3' semi-partial correlation
min_R	Minimal square correlation between indicators (default: 0).
min_comm	Minimal number of indicators per community (default: 2).
Gamma	Gamma parameter in multiresolution null modell (default: 1).
null_modell_type	'1' Differential Newmann-Grivan's null model, '2' The null model is the mean of square correlations between indicators, '3' The null model is the specified minimal square correlation, '4' Newmann-Grivan's modell (default)
mod_mode	Community-based modularity calculation mode: '1' Louvain modularity, '2' Fast-greedy modularity, '3' Leading Eigen modularity, '4' Infomap modularity, '5' Walktrap modularity, '6' Leiden modularity (default)
min_evalue	Minimal eigenvector centrality value (default: 0)
min_communality	Minimal communality value of indicators (default: 0)
com_communalities	Minimal common communalities (default: 0)
use_rotation	FALSE no rotation (default), TRUE the rotation is used.
rotation	"none", "varimax", "quartimax", "promax", "oblimin", "simplimax", and "cluster" are possible rotations/transformations of the solution. "oblimin" is the default, if use_rotation is TRUE.

Details

NDA both works on low and high simple size datasets. If min_evalue=min_communality=com_communalities=0 than there is no feature selection.

Value

communality	Communality estimates for each item. These are merely the sum of squared factor loadings for that item. It can be interpreted in correlation matrices.
loadings	A standard loading matrix of class "loadings".
uniqueness	Uniqueness values of indicators.
factors	Number of found factors.
scores	Estimates of the factor scores are reported (if covar=FALSE).
n.obs	Number of observations specified or found.
fn	Factor name: NDA
Call	Callback function

Author(s)

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References

Kosztyan, Z. T., Kurbucz, M. T., & Katona, A. I. (2022). Network-based dimensionality reduction of high-dimensional, low-sample-size datasets. Knowledge-Based Systems, 109180. doi:10.1016/j.knosys.2022.109180

See Also

plot, biplot, summary.

Examples

```
# Dimension reduction

data(swiss)
df<-swiss
p<-ndr(df)
summary(p)
plot(p)
biplot(p)

# Data reduction
# Distance is Euclidean's distance
# covar=TRUE means only the distance matrix is considered.

q<-ndr(1-normalize(as.matrix(dist(df))),covar=TRUE)
summary(q)
plot(q)
```

---

normalize *Min-max normalization*

Description

Min-max normalization for data matrices and data frames

Usage

```
normalize(x,type="all")
```

Arguments

x	A data frame or data matrix.
type	The type of normalization. "row" normalization row by row, "col" normalization column by column, and "all" normalization for the entire data frame/matrix (default)

Value

Returns a normalized data.frame/matrix.

Author(s)

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Examples

```
mtx<-matrix(rnorm(20),5,4)
n_mtx<-normalize(mtx) # Fully normalized matrix
r_mtx<-normalize(mtx,type="row") # Normalize row by row
c_mtx<-normalize(mtx,type="col") # Normalize col by col
print(n_mtx) # Print fully normalized matrix
```

---

pdCor *Calculating partial distance correlation of columns of a matrix*

Description

Calculating partial distance correlation of two columns of a matrix for Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

The calculation is very slow for large matrices!

Usage

```
pdCor(x)
```

Arguments

x	a a numeric matrix, or a numeric data frame

Value

Partial distance correlation matrix of x.

Author(s)

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References

Rizzo M, Szekely G (2021). _energy: E-Statistics: Multivariate Inference via the Energy of Data_. R package version 1.7-8, <URL: https://CRAN.R-project.org/package=energy>.

Examples

```
# Specification of partial distance correlaction matrix.
x<-matrix(rnorm(36),nrow=6)
pdCor(x)
```

`plot.nda` *Plot function for Generalized Network-based Dimensionality Reduction and Analysis (GNDA)*

Description

Plot variable network graph

Usage

```
## S3 method for class 'nda'
plot(x, cuts=0.3, interactive=TRUE,edgescale=1.0,labeldist=-1.5,show_weights=FALSE,...)
```

Arguments

`x`	an object of class 'NDA'.
`cuts`	minimal square correlation value for an edge in the correlation network graph (default 0.3).
`interactive`	Plot interactive visNetwork graph or non-interactive igraph plot (default TRUE).
`edgescale`	Proportion scale value of edge width.
`labeldist`	Vertex label distance in non-interactive igraph plot (default value =-1.5).
`show_weights`	Show edge weights (default FALSE)).
`...`	other graphical parameters.

Author(s)

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References

Kosztyán, Z. T., Katona, A. I., Kurbucz, M. T., & Lantos, Z. (2024). Generalized network-based dimensionality analysis. Expert Systems with Applications, 238, 121779. <URL: https://doi.org/10.1016/j.eswa.2023.121779>

See Also

`biplot`, `summary`, `ndr`.

Examples

```
# Plot function with feature selection

data("CrimesUSA1990.X")
df<-CrimesUSA1990.X
p<-ndr(df)
biplot(p,main="Biplot of CrimesUSA1990 without feature selection")

# Plot function with feature selection
# minimal eigen values (min_evalue) is 0.0065
# minimal communality value (min_communality) is 0.1
# minimal common communality value (com_communalities) is 0.1

p<-ndr(df,min_evalue = 0.0065,min_communality = 0.1,com_communalities = 0.1)

# Plot with default (cuts=0.3)
plot(p)

# Plot with higher cuts
plot(p,cuts=0.6)

# GNDA is used for clustering, where the similarity function is the 1-Euclidean distance
# Data is the swiss data

SIM<-1-normalize(as.matrix(dist(swiss)))
q<-ndr(SIM,covar = TRUE)
plot(q,interactive = FALSE)
```

`print.nda` *Print function of Generalized Network-based Dimensionality Reduction and Analysis (GNDA)*

Description

Print summary of Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Usage

```
## S3 method for class 'nda'
print(x, digits = getOption("digits"), ...)
```

Arguments

`x`	an object of class 'nda'.
`digits`	the number of significant digits to use when `add.stats = TRUE`.
`...`	additional arguments affecting the summary produced.

Author(s)

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References

Kosztyán, Z. T., Katona, A. I., Kurbucz, M. T., & Lantos, Z. (2024). Generalized network-based dimensionality analysis. Expert Systems with Applications, 238, 121779. <URL: https://doi.org/10.1016/j.eswa.2023.121779>

See Also

biplot, plot, summary, ndr.

Examples

```
# Example of summary function of NDA without feature selection

data("CrimesUSA1990.X")
df<-CrimesUSA1990.X
p<-ndr(df)
summary(p)

# Example of summary function of NDA with feature selection
# minimal eigen values (min_evalue) is 0.0065
# minimal communality value (min_communality) is 0.1
# minimal common communality value (com_communalities) is 0.1

p<-ndr(df,min_evalue = 0.0065,min_communality = 0.1,com_communalities = 0.1)
print(p)
```

---

spdCor *Calculating semi-partial distance correlation of columns of a matrix*

Description

Calculating semi-partial distance correlation of two columns of a matrix for Generalized Network-based Dimensionality Reduction and Analysis (GNDA).

The calculation is very slow for large matrices!

Usage

```
spdCor(x)
```

Arguments

x	a a numeric matrix, or a numeric data frame

Value

Semi-partial distance correlation matrix of x.

Author(s)

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References

Rizzo M, Szekely G (2021). _energy: E-Statistics: Multivariate Inference via the Energy of Data_. R package version 1.7-8, <URL: https://CRAN.R-project.org/package=energy>.

Examples

```
# Specification of semi-partial distance correlaction matrix.
x<-matrix(rnorm(36),nrow=6)
spdCor(x)
```

---

summary.nda *Summary function of Generalized Network-based Dimensionality Reduction and Analysis (GNDA)*

Description

Print summary of Generalized Network-based Dimensionality Reduction and Analysis (GNDA)

Usage

```
## S3 method for class 'nda'
summary(object, digits = getOption("digits"), ...)
```

Arguments

object	an object of class 'nda'.
digits	the number of significant digits to use when add.stats = TRUE.
...	additional arguments affecting the summary produced.

Value

communality	Communality estimates for each item. These are merely the sum of squared factor loadings for that item. It can be interpreted in correlation matrices.
loadings	A standard loading matrix of class "loadings".
uniqueness	Uniqueness values of indicators.
factors	Number of found factors.
scores	Estimates of the factor scores are reported (if covar=FALSE).
n.obs	Number of observations specified or found.

Author(s)

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References

Kosztyán, Z. T., Katona, A. I., Kurbucz, M. T., & Lantos, Z. (2024). Generalized network-based dimensionality analysis. Expert Systems with Applications, 238, 121779. <URL: https://doi.org/10.1016/j.eswa.2023.121779>

See Also

biplot, plot, print, ndr.

Examples

```
# Example of summary function of NDA without feature selection

data("CrimesUSA1990.X")
df<-CrimesUSA1990.X
p<-ndr(df)
summary(p)

# Example of summary function of NDA with feature selection
# minimal eigen values (min_evalue) is 0.0065
# minimal communality value (min_communality) is 0.1
# minimal common communality value (com_communalities) is 0.1

p<-ndr(df,min_evalue = 0.0065,min_communality = 0.1,com_communalities = 0.1)
summary(p)
```

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