Package 'logisticPCA'

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Description Dimensionality reduction techniques for binary data including logistic PCA.

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Contents

`logisticPCA-package` *logisticPCA-package*

Description

Dimension reduction techniques for binary data including logistic PCA

Author(s)

Andrew J. Landgraf

`convexLogisticPCA` *Convex Logistic Principal Component Analysis*

Description

Dimensionality reduction for binary data by extending Pearson's PCA formulation to minimize Binomial deviance. The convex relaxation to projection matrices, the Fantope, is used.

Usage

```
convexLogisticPCA(x, k = 2, m = 4, quiet = TRUE, partial_decomp = FALSE,
  max_iters = 1000, conv_criteria = 1e-06, random_start = FALSE, start_H,
  mu, main_effects = TRUE, ss_factor = 4, weights, M)
```

Arguments

`x`	matrix with all binary entries
`k`	number of principal components to return
`m`	value to approximate the saturated model
`quiet`	logical; whether the calculation should give feedback
`partial_decomp`	logical; if `TRUE`, the function uses the rARPACK package to quickly initialize `H` when `ncol(x)` is large and `k` is small
`max_iters`	number of maximum iterations
`conv_criteria`	convergence criteria. The difference between average deviance in successive iterations
`random_start`	logical; whether to randomly inititalize the parameters. If `FALSE`, function will use an eigen-decomposition as starting value
`start_H`	starting value for the Fantope matrix
`mu`	main effects vector. Only used if `main_effects = TRUE`
`main_effects`	logical; whether to include main effects in the model
`ss_factor`	step size multiplier. Amount by which to multiply the step size. Quadratic convergence rate can be proven for `ss_factor = 1`, but I have found higher values sometimes work better. The default is `ss_factor = 4`. If it is not converging, try `ss_factor = 1`.
`weights`	an optional matrix of the same size as the `x` with non-negative weights
`M`	depricated. Use `m` instead

Value

An S3 object of class `clpca` which is a list with the following components:

`mu`	the main effects
`H`	a rank `k` Fantope matrix
`U`	a `ceiling(k)`-dimentional orthonormal matrix with the loadings
`PCs`	the princial component scores
`m`	the parameter inputed
`iters`	number of iterations required for convergence
`loss_trace`	the trace of the average negative log likelihood using the Fantope matrix
`proj_loss_trace`	the trace of the average negative log likelihood using the projection matrix
`prop_deviance_expl`	the proportion of deviance explained by this model. If `main_effects = TRUE`, the null model is just the main effects, otherwise the null model estimates 0 for all natural parameters.

References

Landgraf, A.J. & Lee, Y., 2015. Dimensionality reduction for binary data through the projection of natural parameters. arXiv preprint arXiv:1510.06112.

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run convex logistic PCA on it
clpca = convexLogisticPCA(mat, k = 1, m = 4)
```

`cv.clpca` *CV for convex logistic PCA*

Description

Run cross validation on dimension and `m` for convex logistic PCA

Usage

```
cv.clpca(x, ks, ms = seq(2, 10, by = 2), folds = 5, quiet = TRUE, Ms, ...)
```

Arguments

`x`	matrix with all binary entries
`ks`	the different dimensions `k` to try
`ms`	the different approximations to the saturated model `m` to try
`folds`	if `folds` is a scalar, then it is the number of folds. If it is a vector, it should be the same length as the number of rows in `x`
`quiet`	logical; whether the function should display progress
`Ms`	depricated. Use `ms` instead
`...`	Additional arguments passed to convexLogisticPCA

Value

A matrix of the CV negative log likelihood with `k` in rows and `m` in columns

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))
```

```
# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

## Not run:
negloglikes = cv.clpca(mat, ks = 1:9, ms = 3:6)
plot(negloglikes)

## End(Not run)
```

---

cv.lpca *CV for logistic PCA*

Description

Run cross validation on dimension and `m` for logistic PCA

Usage

```
cv.lpca(x, ks, ms = seq(2, 10, by = 2), folds = 5, quiet = TRUE, Ms, ...)
```

Arguments

`x`	matrix with all binary entries
`ks`	the different dimensions `k` to try
`ms`	the different approximations to the saturated model `m` to try
`folds`	if `folds` is a scalar, then it is the number of folds. If it is a vector, it should be the same length as the number of rows in `x`
`quiet`	logical; whether the function should display progress
`Ms`	depricated. Use `ms` instead
`...`	Additional arguments passed to `logisticPCA`

Value

A matrix of the CV negative log likelihood with `k` in rows and `m` in columns

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

## Not run:
```

```
negloglikes = cv.lpca(mat, ks = 1:9, ms = 3:6)
plot(negloglikes)

## End(Not run)
```

---

cv.lsvd *CV for logistic SVD*

Description

Run cross validation on dimension for logistic SVD

Usage

```
cv.lsvd(x, ks, folds = 5, quiet = TRUE, ...)
```

Arguments

x	matrix with all binary entries
ks	the different dimensions k to try
folds	if folds is a scalar, then it is the number of folds. If it is a vector, it should be the same length as the number of rows in x
quiet	logical; whether the function should display progress
...	Additional arguments passed to logisticSVD

Value

A matrix of the CV negative log likelihood with k in rows

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

## Not run:
negloglikes = cv.lsvd(mat, ks = 1:9)
plot(negloglikes)

## End(Not run)
```

fitted.lpca *Fitted values using logistic PCA*

Description

Fit a lower dimentional representation of the binary matrix using logistic PCA

Usage

```
## S3 method for class 'lpca'
fitted(object, type = c("link", "response"), ...)
```

Arguments

object	logistic PCA object
type	the type of fitting required. type = "link" gives output on the logit scale and type = "response" gives output on the probability scale
...	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic PCA on it
lpca = logisticPCA(mat, k = 1, m = 4, main_effects = FALSE)

# construct fitted probability matrix
fit = fitted(lpca, type = "response")
```

fitted.lsvd *Fitted values using logistic SVD*

Description

Fit a lower dimentional representation of the binary matrix using logistic SVD

Usage

```
## S3 method for class 'lsvd'
fitted(object, type = c("link", "response"), ...)
```

Arguments

`object`	logistic SVD object
`type`	the type of fitting required. `type = "link"` gives output on the logit scale and `type = "response"` gives output on the probability scale
`...`	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic SVD on it
lsvd = logisticSVD(mat, k = 1, main_effects = FALSE, partial_decomp = FALSE)

# construct fitted probability matrix
fit = fitted(lsvd, type = "response")
```

`house_votes84` *United States Congressional Voting Records 1984*

Description

This data set includes votes for each of the U.S. House of Representatives Congressmen on the 16 key votes identified by the CQA. The CQA lists nine different types of votes: voted for, paired for, and announced for (these three simplified to yea), voted against, paired against, and announced against (these three simplified to nay), voted present, voted present to avoid conflict of interest, and did not vote or otherwise make a position known (these three simplified to an unknown disposition).

Usage

```
house_votes84
```

Format

A matrix with all binary or missing entries. There are 435 rows corresponding members of congress and 16 columns representing the bills being voted on. The row names refer to the political party of the members of congress

Source

Congressional Quarterly Almanac, 98th Congress, 2nd session 1984, Volume XL: Congressional Quarterly Inc., Washington, D.C., 1985

Data converted to a matrix from:

Lichman, M. (2013). UCI Machine Learning Repository [http://archive.ics.uci.edu/ml]. Irvine, CA: University of California, School of Information and Computer Science.

Examples

```
data(house_votes84)
congress_lpca = logisticPCA(house_votes84, k = 2, m = 4)
```

---

inv.logit.mat *Inverse logit for matrices*

Description

Apply the inverse logit function to a matrix, element-wise. It generalizes the `inv.logit` function from the `gtools` library to matrices

Usage

```
inv.logit.mat(x, min = 0, max = 1)
```

Arguments

`x`	matrix
`min`	Lower end of logit interval
`max`	Upper end of logit interval

Examples

```
(mat = matrix(rnorm(10 * 5), nrow = 10, ncol = 5))
inv.logit.mat(mat)
```

`logisticPCA` *Logistic Principal Component Analysis*

Description

Dimensionality reduction for binary data by extending Pearson's PCA formulation to minimize Binomial deviance

Usage

```
logisticPCA(x, k = 2, m = 4, quiet = TRUE, partial_decomp = FALSE,
  max_iters = 1000, conv_criteria = 1e-05, random_start = FALSE, start_U,
  start_mu, main_effects = TRUE, validation, M, use_irlba)
```

Arguments

`x`	matrix with all binary entries
`k`	number of principal components to return
`m`	value to approximate the saturated model. If `m = 0`, m is solved for
`quiet`	logical; whether the calculation should give feedback
`partial_decomp`	logical; if `TRUE`, the function uses the rARPACK package to more quickly calculate the eigen-decomposition. This is usually faster than standard eigen-decomponsition when `ncol(x) > 100` and `k` is small
`max_iters`	number of maximum iterations
`conv_criteria`	convergence criteria. The difference between average deviance in successive iterations
`random_start`	logical; whether to randomly inititalize the parameters. If `FALSE`, function will use an eigen-decomposition as starting value
`start_U`	starting value for the orthogonal matrix
`start_mu`	starting value for mu. Only used if `main_effects = TRUE`
`main_effects`	logical; whether to include main effects in the model
`validation`	optional validation matrix. If supplied and `m = 0`, the validation data is used to solve for `m`
`M`	depricated. Use `m` instead
`use_irlba`	depricated. Use `partial_decomp` instead

Value

An S3 object of class `lpca` which is a list with the following components:

`mu`	the main effects
`U`	a `k`-dimentional orthonormal matrix with the loadings
`PCs`	the princial component scores

`m` the parameter inputed or solved for

`iters` number of iterations required for convergence

`loss_trace` the trace of the average negative log likelihood of the algorithm. Should be non-increasing

`prop_deviance_expl`
: the proportion of deviance explained by this model. If `main_effects = TRUE`, the null model is just the main effects, otherwise the null model estimates 0 for all natural parameters.

References

Landgraf, A.J. & Lee, Y., 2015. Dimensionality reduction for binary data through the projection of natural parameters. arXiv preprint arXiv:1510.06112.

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic PCA on it
lpca = logisticPCA(mat, k = 1, m = 4, main_effects = FALSE)

# Logistic PCA likely does a better job finding latent features
# than standard PCA
plot(svd(mat_logit)$u[, 1], lpca$PCs[, 1])
plot(svd(mat_logit)$u[, 1], svd(mat)$u[, 1])
```

`logisticSVD` *Logistic Singular Value Decomposition*

Description

Dimensionality reduction for binary data by extending SVD to minimize binomial deviance.

Usage

```
logisticSVD(x, k = 2, quiet = TRUE, max_iters = 1000,
  conv_criteria = 1e-05, random_start = FALSE, start_A, start_B, start_mu,
  partial_decomp = TRUE, main_effects = TRUE, use_irlba)
```

Arguments

x	matrix with all binary entries
k	rank of the SVD
quiet	logical; whether the calculation should give feedback
max_iters	number of maximum iterations
conv_criteria	convergence criteria. The difference between average deviance in successive iterations
random_start	logical; whether to randomly inititalize the parameters. If FALSE, algorithm will use an SVD as starting value
start_A	starting value for the left singular vectors
start_B	starting value for the right singular vectors
start_mu	starting value for mu. Only used if main_effects = TRUE
partial_decomp	logical; if TRUE, the function uses the rARPACK package to more quickly calculate the SVD. When the number of columns is small, the approximation may be less accurate and slower
main_effects	logical; whether to include main effects in the model
use_irlba	depricated. Use partial_decomp instead

Value

An S3 object of class lsvd which is a list with the following components:

mu	the main effects
A	a k-dimentional orthogonal matrix with the scaled left singular vectors
B	a k-dimentional orthonormal matrix with the right singular vectors
iters	number of iterations required for convergence
loss_trace	the trace of the average negative log likelihood of the algorithm. Should be non-increasing
prop_deviance_expl	the proportion of deviance explained by this model. If main_effects = TRUE, the null model is just the main effects, otherwise the null model estimates 0 for all natural parameters.

References

de Leeuw, Jan, 2006. Principal component analysis of binary data by iterated singular value decomposition. Computational Statistics & Data Analysis 50 (1), 21–39.

Collins, M., Dasgupta, S., & Schapire, R. E., 2001. A generalization of principal components analysis to the exponential family. In NIPS, 617–624.

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic SVD on it
lsvd = logisticSVD(mat, k = 1, main_effects = FALSE, partial_decomp = FALSE)

# Logistic SVD likely does a better job finding latent features
# than standard SVD
plot(svd(mat_logit)$u[, 1], lsvd$A[, 1])
plot(svd(mat_logit)$u[, 1], svd(mat)$u[, 1])
```

`log_like_Bernoulli` *Bernoulli Log Likelihood*

Description

Calculate the Bernoulli log likelihood of matrix

Usage

```
log_like_Bernoulli(x, theta, q)
```

Arguments

`x`	matrix with all binary entries
`theta`	estimated natural parameters with same dimensions as x
`q`	instead of x, you can input matrix q which is -1 if `x = 0`, 1 if `x = 1`, and 0 if `is.na(x)`

`plot.clpca` *Plot convex logistic PCA*

Description

Plots the results of a convex logistic PCA

Usage

```
## S3 method for class 'clpca'
plot(x, type = c("trace", "loadings", "scores"), ...)
```

Arguments

`x`	convex logistic PCA object
`type`	the type of plot `type = "trace"` plots the algorithms progress by iteration, `type = "loadings"` plots the first 2 PC loadings, `type = "scores"` plots the first 2 PC scores
`...`	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run convex logistic PCA on it
clpca = convexLogisticPCA(mat, k = 2, m = 4, main_effects = FALSE)

## Not run:
plot(clpca)

## End(Not run)
```

`plot.cv.lpca` *Plot CV for logistic PCA*

Description

Plot cross validation results logistic PCA

Usage

```
## S3 method for class 'cv.lpca'
plot(x, ...)
```

Arguments

`x`	a `cv.lpca` object
`...`	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

## Not run:
negloglikes = cv.lpca(dat, ks = 1:9, ms = 3:6)
plot(negloglikes)

## End(Not run)
```

---

plot.lpca *Plot logistic PCA*

Description

Plots the results of a logistic PCA

Usage

```
## S3 method for class 'lpca'
plot(x, type = c("trace", "loadings", "scores"), ...)
```

Arguments

x	logistic PCA object
type	the type of plot `type = "trace"` plots the algorithms progress by iteration, `type = "loadings"` plots the first 2 principal component loadings, `type = "scores"` plots the loadings first 2 principal component scores
...	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic PCA on it
```

```
lpca = logisticPCA(mat, k = 2, m = 4, main_effects = FALSE)

## Not run:
plot(lpca)

## End(Not run)
```

---

plot.lsvd *Plot logistic SVD*

Description

Plots the results of a logistic SVD

Usage

```
## S3 method for class 'lsvd'
plot(x, type = c("trace", "loadings", "scores"), ...)
```

Arguments

x	logistic SVD object
type	the type of plot type = "trace" plots the algorithms progress by iteration, type = "loadings" plots the first 2 principal component loadings, type = "scores" plots the loadings first 2 principal component scores
...	Additional arguments

Examples

```
# construct a low rank matrix in the logit scale
rows = 100
cols = 10
set.seed(1)
mat_logit = outer(rnorm(rows), rnorm(cols))

# generate a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0

# run logistic SVD on it
lsvd = logisticSVD(mat, k = 2, main_effects = FALSE, partial_decomp = FALSE)

## Not run:
plot(lsvd)

## End(Not run)
```

predict.clpca *Predict Convex Logistic PCA scores or reconstruction on new data*

Description

Predict Convex Logistic PCA scores or reconstruction on new data

Usage

```
## S3 method for class 'clpca'
predict(object, newdata, type = c("PCs", "link", "response"),
  ...)
```

Arguments

`object`	convex logistic PCA object
`newdata`	matrix with all binary entries. If missing, will use the data that `object` was fit on
`type`	the type of fitting required. `type = "PCs"` gives the PC scores, `type = "link"` gives matrix on the logit scale and `type = "response"` gives matrix on the probability scale
`...`	Additional arguments

Examples

```
# construct a low rank matrices in the logit scale
rows = 100
cols = 10
set.seed(1)
loadings = rnorm(cols)
mat_logit = outer(rnorm(rows), loadings)
mat_logit_new = outer(rnorm(rows), loadings)

# convert to a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0
mat_new = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit_new)) * 1.0

# run logistic PCA on it
clpca = convexLogisticPCA(mat, k = 1, m = 4, main_effects = FALSE)

PCs = predict(clpca, mat_new)
```

`predict.lpca` *Predict Logistic PCA scores or reconstruction on new data*

Description

Predict Logistic PCA scores or reconstruction on new data

Usage

```
## S3 method for class 'lpca'
predict(object, newdata, type = c("PCs", "link", "response"),
  ...)
```

Arguments

`object`	logistic PCA object
`newdata`	matrix with all binary entries. If missing, will use the data that `object` was fit on
`type`	the type of fitting required. `type = "PCs"` gives the PC scores, `type = "link"` gives matrix on the logit scale and `type = "response"` gives matrix on the probability scale
`...`	Additional arguments

Examples

```
# construct a low rank matrices in the logit scale
rows = 100
cols = 10
set.seed(1)
loadings = rnorm(cols)
mat_logit = outer(rnorm(rows), loadings)
mat_logit_new = outer(rnorm(rows), loadings)

# convert to a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0
mat_new = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit_new)) * 1.0

# run logistic PCA on it
lpca = logisticPCA(mat, k = 1, m = 4, main_effects = FALSE)

PCs = predict(lpca, mat_new)
```

predict.lsvd *Predict Logistic SVD left singular values or reconstruction on new data*

Description

Predict Logistic SVD left singular values or reconstruction on new data

Usage

```
## S3 method for class 'lsvd'
predict(object, newdata, quiet = TRUE, max_iters = 1000,
  conv_criteria = 1e-05, random_start = FALSE, start_A, type = c("PCs",
  "link", "response"), ...)
```

Arguments

`object`	logistic SVD object
`newdata`	matrix with all binary entries. If missing, will use the data that `object` was fit on
`quiet`	logical; whether the calculation should give feedback
`max_iters`	number of maximum iterations
`conv_criteria`	convergence criteria. The difference between average deviance in successive iterations
`random_start`	logical; whether to randomly inititalize the parameters. If `FALSE`, algorithm implicitly starts `A` with 0 matrix
`start_A`	starting value for the left singular vectors
`type`	the type of fitting required. `type = "PCs"` gives the left singular vectors, `type = "link"` gives matrix on the logit scale and `type = "response"` gives matrix on the probability scale
`...`	Additional arguments

Details

Minimizes binomial deviance for new data by finding the optimal left singular vector matrix (`A`), given `B` and `mu`. Assumes the columns of the right singular vector matrix (`B`) are orthonormal.

Examples

```
# construct a low rank matrices in the logit scale
rows = 100
cols = 10
set.seed(1)
loadings = rnorm(cols)
mat_logit = outer(rnorm(rows), loadings)
mat_logit_new = outer(rnorm(rows), loadings)
```

```
# convert to a binary matrix
mat = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit)) * 1.0
mat_new = (matrix(runif(rows * cols), rows, cols) <= inv.logit.mat(mat_logit_new)) * 1.0

# run logistic PCA on it
lsvd = logisticSVD(mat, k = 1, main_effects = FALSE, partial_decomp = FALSE)

A_new = predict(lsvd, mat_new)
```

---

project.Fantope *Project onto the Fantope*

Description

Project a symmetric matrix onto the convex set of the rank k Fantope

Usage

```
project.Fantope(x, k)
```

Arguments

x	a symmetric matrix
k	the rank of the Fantope desired

Value

H	a rank k Fantope matrix
U	a k-dimentional orthonormal matrix with the first k eigenvectors of H

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