Package ‘lfa’

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Title Logistic Factor Analysis for Categorical Data
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Description Logistic Factor Analysis is a method for a PCA analogue on Binomial data via estimation of latent structure in the natural parameter. The main method estimates genetic population structure from genotype data. There are also methods for estimating individual-specific allele frequencies using the population structure. Lastly, a structured Hardy-Weinberg equilibrium (HWE) test is developed, which quantifies the goodness of fit of the genotype data to the estimated population structure, via the estimated individual-specific allele frequencies (all of which generalizes traditional HWE tests).

Imports utils, methods, corpcor, RSpectra
Depends R (>= 4.0)
Suggests knitr, ggplot2, testthat, BEDMatrix, genio
VignetteBuilder knitr
License GPL (>= 3)

biocViews SNP, DimensionReduction, PrincipalComponent, Regression

BugReports https://github.com/StoreyLab/lfa/issues

URL https://github.com/StoreyLab/lfa

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Af

Allele frequencies

Description
Compute matrix of individual-specific allele frequencies

Usage
af(X, LF, safety = FALSE, max_iter = 100, tol = 1e-10)

Arguments

X
A matrix of SNP genotypes, i.e. an integer matrix of 0's, 1's, 2's and NAs. BEDMatrix is supported. Sparse matrices of class Matrix are not supported (yet).

LF
Matrix of logistic factors, with intercept. Pass in the return value from lfa()

safety
Optional boolean to bypass checks on the genotype matrices, which require a non-trivial amount of computation. Ignored if X is a BEDMatrix object.

max_iter
Maximum number of iterations for logistic regression

tol
Numerical tolerance for convergence of logistic regression
af_snp

Details

Computes the matrix of individual-specific allele frequencies, which has the same dimensions of the genotype matrix. Be warned that this function could use a ton of memory, as the return value is all doubles. It could be wise to pass only a selection of the SNPs in your genotype matrix to get an idea for memory usage. Use gc() to check memory usage!

Value

Matrix of individual-specific allele frequencies.

Examples

LF <- lfa(hgdp_subset, 4)
allele_freqs <- af(hgdp_subset, LF)

Description

Computes individual-specific allele frequencies for a single SNP.

Usage

af_snp(snp, LF, max_iter = 100, tol = 1e-10)

Arguments

snp vector of 0’s, 1’s, and 2’s
LF Matrix of logistic factors, with intercept. Pass in the return value from lfa()!
max_iter Maximum number of iterations for logistic regression
tol Numerical tolerance for convergence of logistic regression

Value

vector of allele frequencies

See Also

af()

Examples

LF <- lfa(hgdp_subset, 4)
# pick one SNP only
snp <- hgdp_subset[, 1]
# allele frequency vector for that SNP only
allele_freqs_snp <- af_snp(snp, LF)
Description

The functions listed below are deprecated and will be defunct in the near future. When possible, alternative functions with similar functionality are also mentioned. Help pages for deprecated functions are available at help("<function>-deprecated").

Usage

center(A)

model.gof(X, LF, B)

read.bed(bed.prefix)

read.tped.recode(tped.filename, buffer.size = 5e+08)

Value

Function-dependent

center

For center, use function(x) x - rowMeans(x).

model.gof

For model.gof, use shWE().

read.bed

For read.bed, use genio::read_plink().

read.tped.recode

For read.tped.recode, use plink (external binary) to convert to BED/BIM/FAM, then parse with genio::read_plink().
center-deprecated

**Matrix centering**

**Description**
C routine to row-center a matrix

**Usage**
```r
center(A)
```

**Arguments**
- `A`: matrix

**Value**
- `A` but row centered

**See Also**
- `lfa-deprecated()`

---

centerscale

**Matrix centering and scaling**

**Description**
C routine to row-center and scale a matrix. Doesn’t work with missing data.

**Usage**
```r
centerscale(A)
```

**Arguments**
- `A`: matrix

**Value**
- matrix same dimensions as `A` but row centered and scaled

**Examples**
```r
Xc <- centerscale(hgdp_subset)
```
**Description**

Subset of the HGDP dataset.

**Usage**

```r
hgdp_subset
```

**Format**

a matrix of 0’s, 1’s and 2’s.

**Value**

genotype matrix

**Source**


---

**lfa**

*Logistic factor analysis*

**Description**

Fit logistic factor model of dimension \(d\) to binomial data. Computes \(d - 1\) singular vectors followed by intercept.

**Usage**

```r
lfa(
  x,
  d,
  adjustments = NULL,
  override = FALSE,
  safety = FALSE,
  rspectra = FALSE,
  ploidy = 2,
  tol = .Machine$double.eps,
  m_chunk = 1000
)
```
Arguments

X  A matrix of SNP genotypes, i.e. an integer matrix of 0’s, 1’s, 2’s and NAs. BEDMatrix is supported. Sparse matrices of class Matrix are not supported (yet).

d  Number of logistic factors, including the intercept

adjustments  A matrix of adjustment variables to hold fixed during estimation. Number of rows must equal number of individuals in X. These adjustments take the place of LFs in the output, so the number of columns must not exceed d-2 to allow for the intercept and at least one proper LF to be included. When present, these adjustment variables appear in the first columns of the output. Not supported when X is a BEDMatrix object.

override  Optional boolean passed to trunc_svd() to bypass its Lanczos bidiagonalization SVD, instead using corpcor::fast.svd(). Usually not advised unless encountering a bug in the SVD code. Ignored if X is a BEDMatrix object.

safety  Optional boolean to bypass checks on the genotype matrices, which require a non-trivial amount of computation. Ignored if X is a BEDMatrix object.

rspectra  If TRUE, use RSpectra::svds() instead of default trunc_svd() or corpcor::fast.svd() options. Ignored if X is a BEDMatrix object.

ploidy  Ploidy of data, defaults to 2 for bi-allelic unphased SNPs

tol  Tolerance value passed to trunc_svd() Ignored if X is a BEDMatrix object.

m_chunk  If X is a BEDMatrix object, number of loci to read per chunk (to control memory usage).

Details

Genotype matrix should have values in 0, 1, 2, or NA. The coding of the SNPs (which case is 0 vs 2) does not change the output.

Value

The matrix of logistic factors, with individuals along rows and factors along columns. The intercept appears at the end of the columns, and adjustments in the beginning if present.

Examples

LF <- lfa(hgdp_subset, 4)
dim(LF)
head(LF)
Description

Compute SNP-by-SNP goodness-of-fit when compared to population structure. This can be aggregated to determine genome-wide goodness-of-fit for a particular value of \( d \).

Usage

\[
\text{model.gof}(X, LF, B)
\]

Arguments

- **X**: A matrix of SNP genotypes, i.e. an integer matrix of 0’s, 1’s, 2’s and NAs. BEDMatrix is supported.
- **LF**: matrix of logistic factors
- **B**: number of null datasets to generate, \( B = 1 \) is usually sufficient. If computational time/power allows, a few extra \( B \) could be helpful

Details

This function returns p-values for LFA model goodness of fit based on a simulated null.

Value

- vector of p-values for each SNP.

Note

Genotype matrix is expected to be a matrix of integers with values 0, 1, and 2. Currently no support for missing values. Note that the coding of the SNPs does not affect the algorithm.

See Also

- `lfa-deprecated()`
**Description**

Compute matrix of individual-specific allele frequencies via PCA

**Usage**

```r
pca_af(X, d, override = FALSE, ploidy = 2, tol = 1e-13, m_chunk = 1000)
```

**Arguments**

- `X` A matrix of SNP genotypes, i.e. an integer matrix of 0’s, 1’s, 2’s and NAs. BEDMatrix is supported. Sparse matrices of class Matrix are not supported (yet).
- `d` Number of logistic factors, including the intercept
- `override` Optional boolean passed to `trunc_svd()` to bypass its Lanczos bidiagonalization SVD, instead using `corpcor::fast.svd()`. Usually not advised unless encountering a bug in the SVD code. Ignored if `X` is a BEDMatrix object.
- `ploidy` Ploidy of data, defaults to 2 for bi-allelic unphased SNPs
- `tol` Tolerance value passed to `trunc_svd()` Ignored if `X` is a BEDMatrix object.
- `m_chunk` If `X` is a BEDMatrix object, number of loci to read per chunk (to control memory usage).

**Details**

This corresponds to algorithm 1 in the paper. Only used for comparison purposes.

**Value**

Matrix of individual-specific allele frequencies.

**Examples**

```r
LF <- lfa(hgdp_subset, 4)
allele_freqs_lfa <- af(hgdp_subset, LF)
allele_freqs_pca <- pca_af(hgdp_subset, 4)
summary(abs(allele_freqs_lfa-allele_freqs_pca))
```
**read.bed.deprecated**

*File input: .bed*

**Description**

Reads in genotypes in .bed format with corresponding bim and fam files.

**Usage**

```r
read.bed(bed.prefix)
```

**Arguments**

- `bed.prefix`: Path leading to the bed, bim, and fam files.

**Details**

Use plink with `--make-bed`

**Value**

Genotype matrix

**See Also**

`lfa.deprecated()`

---

**read.tped.recode.deprecated**

*Read .tped*

**Description**

Reads a .tped format genotype matrix and returns the R object needed by `lfa`.

**Usage**

```r
read.tped.recode(tped.filename, buffer.size=5e8)
```

**Arguments**

- `tped.filename`: Path to your .tped file after tranposing and recoding.
- `buffer.size`: Number of characters to keep in the buffer.
sHWE

Details

Use –transpose and –recode12 on your plink formatted genotypes to generate the proper tped file. This is a pretty terrible function that uses a growing matrix for the genotypes so it is to your benefit to have as large a buffer.size as possible.

Value

genotype matrix with elements 0, 1, 2, and NA.

See Also

lfa-deprecated()

Examples

#assuming you have a .tped file in the right directory
x = NULL
## Not run: x = read.tped.recode('file.tped')

---

sHWE

Hardy-Weinberg Equilibrium in structure populations

Description

Compute structural Hardy-Weinberg Equilibrium (sHWE) p-values on a SNP-by-SNP basis. These p-values can be aggregated to determine genome-wide goodness-of-fit for a particular value of d. See doi:10.1101/240804 for more details.

Usage

sHWE(X, LF, B, max_iter = 100, tol = 1e-10)

Arguments

X A matrix of SNP genotypes, i.e. an integer matrix of 0's, 1's, 2's and NAs. BEDMatrix is supported. Sparse matrices of class Matrix are not supported (yet).

LF matrix of logistic factors

B number of null datasets to generate, B = 1 is usually sufficient. If computational time/power allows, a few extra B could be helpful

max_iter Maximum number of iterations for logistic regression

tol Tolerance value passed to trunc_svd() Ignored if X is a BEDMatrix object.

Value

a vector of p-values for each SNP.
Examples

```r
# get LFs
LF <- lfa(hgdp_subset, 4)
# look at a small (300) number of SNPs for rest of this example:
hgdp_subset_small <- hgdp_subset[1:300,]
gof_4 <- shWE(hgdp_subset_small, LF, 3)
LF <- lfa(hgdp_subset, 10)
gof_10 <- shWE(hgdp_subset_small, LF, 3)
hist(gof_4)
hist(gof_10)
```

---

**trunc_svd**  
*Truncated singular value decomposition*

Description

Truncated SVD

Usage

```r
trun_svd(
  A,
  d,
  adjust = 3,
  tol = .Machine$double.eps,
  override = FALSE,
  force = FALSE,
  maxit = 1000
)
```

Arguments

- **A**: matrix to decompose
- **d**: number of singular vectors
- **adjust**: extra singular vectors to calculate for accuracy
- **tol**: convergence criterion
- **override**: TRUE means we use `corpcor::fast.svd()` instead of the iterative algorithm (useful for small data or very high d).
- **force**: If TRUE, forces the Lanczos algorithm to be used on all datasets (usually `corpcor::fast.svd()` is used on small datasets or large d)
- **maxit**: Maximum number of iterations
**Details**

Performs singular value decomposition but only returns the first `d` singular vectors/values. The truncated SVD utilizes Lanczos bidiagonalization. See references.

This function was modified from the package irlba 1.0.1 under GPL. Replacing the `crossprod()` calls with the C wrapper to `dgemv` is a dramatic difference in larger datasets. Since the wrapper is technically not a matrix multiplication function, it seemed wise to make a copy of the function.

**Value**

List with singular value decomposition. Has elements 'd', 'u', 'v', and 'iter'

**Examples**

```r
obj <- trunc_svd( hgdp_subset, 4 )
obj$d
obj$u
obj$v
obj$iter
```
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