Package ‘BoltzMM’

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Probability mass function of a fully-visible Boltzmann machine evaluated for all possible vectors.

Description
Compute the probability of all $2^n$ strings of $n>1$ binary spin variables (i.e. each element is -1 or 1) arising from a fully-visible Boltzmann machine with some specified bias vector and interaction matrix.

Usage
allpfvbm(bvec, Mmat)

Arguments
bvec Vector of length n containing real valued bias parameters.
Mmat Symmetric n by n matrix, with zeros along the diagonal, containing the interaction parameters.

Value
A vector of the probabilities of all $2^n$ binary spin vectors under a fully-visible Boltzmann machine with bias vector bvec and interaction matrix Mmat. Probabilities are reported in ascending order of the binary strings; i.e for n=2 the reporting order is (-1,1), (-1,1), (1,-1), and (1,1).

Author(s)
Andrew T. Jones and Hien D. Nguyen

References

Examples
# Compute the probability of every length n=3 binary spin vector under bvec and Mmat.
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
allpfvbm(bvec,Mmat)
BoltzMM


Description

The BoltzMM package allows for computation of probability mass functions of fully-visible Boltzmann machines via \texttt{pfvbm} and \texttt{allpfvbm}. Random data can be generated using \texttt{rfvbm}. Maximum pseudolikelihood estimation of parameters via the MM algorithm can be conducted using \texttt{fitfvbm}. Computation of partial derivatives and Hessians can be performed via \texttt{fvbmpartiald} and \texttt{fvbmhessian}. Covariance estimation and normal standard errors can be computed using \texttt{fvbmcov} and \texttt{fvbmstderr}.

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


fitfvbm

Maximum pseudolikelihood estimation of a fully-visible Boltzmann machine.

Description

Estimates the bias vector and interaction matrix of a fully-visible Boltzmann machine via maximum pseudolikelihood estimation using an MM algorithm.

Usage

\texttt{fitfvbm(data, bvec, Mmat, delta\_crit = 0.001, max\_it = 1000L)}
**Arguments**

- **data**: An N by n matrix, where each of the N rows contains a length n string of spin variables (i.e. each element is -1 or 1).
- **bvec**: Initial estimate for a vector of length n containing real valued bias parameters.
- **Mmat**: Initial estimate for a symmetric n by n matrix, with zeros along the diagonal, containing the interaction parameters.
- **delta_crit**: Real threshold value for the convergence criterion, based on the relative change in the Euclidean distance of parameter estimates from consecutive iterations.
- **max_it**: Integer value indicating the maximum number of iterations that the algorithm is to run for.

**Value**

A list containing 4 objects: the final log-pseudolikelihood value `pll`, a vector containing the estimate of the bias parameters `bvec`, a matrix containing the estimate of the interaction parameters `Mmat`, and the number of algorithm iterations `itt`.

**Author(s)**

Andrew T. Jones and Hien D. Nguyen

**References**


**Examples**

```r
# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
data <- rfvbm(num,bvec,Mmat)
# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
fitfvbm(data,bvec,Mmat)
```

---

**fvmc**

sandwich estimator of the covariance matrix for a fitted fully-visible Boltzmann machine.

**Description**

Computes the sandwich estimator of the covariance matrix for a maximum pseudolikelihood estimated fully-visible Boltzmann machine.
**Usage**

```r
data, model, fvbmHess
```

**Arguments**

- `data`: An N by n matrix, where each of the N rows contains a length n string of spin variables (i.e. each element is -1 or 1).
- `model`: List generated from `fitfvbm`.
- `fvbmHess`: A function that computes the Hessian of the parameter elements. Currently, the only implemented method is the default `fvbmHess` function.

**Value**

The `n+choose(n,2)` by `n+choose(n,2)` sandwich covariance matrix, estimated using `data` and evaluated at the fitted parameter values provided in `model`. Each row (column) is a unique element of the bias vector and interaction matrix. The rows are arranged in lexicographical order with the bias elements first, followed by the interaction elements. For example, if `n=3`, the order would be `bias[1]`, `bias[2]` `bias[3]`, `interaction[1,2]`, `interaction[1,3]`, and `interaction[2,3]`.

**Author(s)**

Andrew T. Jones and Hien D. Nguyen

**References**


**Examples**

```r
# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
data <- rfvbm(num,bvec,Mmat)
# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
model <- fitfvbm(data,bvec,Mmat)
# Compute the sandwich covariance matrix using the data and the model.
fvbmcov(data,model,fvbmHess)
```
fvbmHess

Hessian of the log-pseudolikelihood function for a fitted fully-visible Boltzmann machine.

Description

Computes the Hessian with respect to all unique parameter elements of the bias vector and interaction matrix of a fully-visible Boltzmann machine, for some random length n string of spin variables (i.e. each element is -1 or 1) and some fitted parameter values.

Usage

fvbmHess(data, model)

Arguments

data An N by n matrix, where each of the N rows contains a length n string of spin variables (i.e. each element is -1 or 1).
model List generated from fitfvbm.

Value

The n+choose(n,2) by n+choose(n,2) Hessian matrix, summed over the N rows of data and evaluated at the fitted parameter values provided in model. Each row (column) is a unique element of the bias vector and interaction matrix. The rows are arranged in lexicographical order with the bias elements first, followed by the interaction elements. For example, if n=3, the order would be bias[1], bias[2] bias[3], interaction[1,2], interaction[1,3], and interaction[2,3].

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


Examples

# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
data <- rfvbm(num,bvec,Mmat)
# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
model <- fitfvbm(data,bvec,Mmat)
# Compute the Hessian matrix summed over all num rows of data.
fvmHess(data,model)
**fvbmpartiald**

Partial derivatives of the log-pseudolikelihood function for a fitted fully-visible Boltzmann machine.

**Description**

Computes the partial derivatives for all unique parameter elements of the bias vector and interaction matrix of a fully-visible Boltzmann machine, for some random length n string of spin variables (i.e. each element is -1 or 1) and some fitted parameter values.

**Usage**

fvbmpartiald(data, model)

**Arguments**

- **data** Vector of length n containing binary spin variables.
- **model** List generated from fitfvbm.

**Value**

A list containing 2 objects: a vector containing the partial derivatives corresponding to the bias parameters bvec, and a matrix containing the partial derivatives corresponding to the interaction parameters Mmat.

**Author(s)**

Andrew T. Jones and Hien D. Nguyen

**References**


**Examples**

```r
# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
data <- rfvbm(num,bvec,Mmat)
# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
model <- fitfvbm(data,bvec,Mmat)
# Compute the partial derivatives evaluated at the first observation of data.
fvbmpartiald(data,model)
```
fvbmstderr

**Standard errors for the parameter elements of a fitted fully-visible Boltzmann machine.**

**Description**

Computes the normal approximation standard errors from the sandwich estimator of the covariance matrix for a maximum pseudolikelihood estimated fully-visible Boltzmann machine.

**Usage**

```r
fvbmstderr(data, covarmat)
```

**Arguments**

- `data`: An N by n matrix, where each of the N rows contains a length n string of spin variables (i.e. each element is -1 or 1).
- `covarmat`: A covariance matrix generated from `fvbmcov`.

**Value**

A list containing 2 objects: a vector containing the standard errors corresponding to the bias parameters `bvec_se`, and a matrix containing the standard errors corresponding to the interaction parameters `mmat_se`.

**Author(s)**

Andrew T. Jones and Hien D. Nguyen

**References**


**Examples**

```r
# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
data <- rfvbm(num,bvec,Mmat)

# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
model <- fitfvbm(data,bvec,Mmat)

# Compute the sandwich covariance matrix using the data and the model.
covarmat <- fvbmcov(data,model,FvbhmHess)

# Compute the standard errors of the parameter elements according to a normal approximation.
fvmstderr(data,covarmat)
```
Hypothesis testing for a fully-visible Boltzmann machine.

Description

Tests the hypothesis that the true bias and interaction parameter values are those in nullmodel, given data and model.

Usage

fvbmtests(data, model, nullmodel)

Arguments

- **data**: An N by n matrix, where each of the N rows contains a length n string of spin variables (i.e. each element is -1 or 1).
- **model**: List generated from fitfvbm.
- **nullmodel**: A list containing two elements: a vector of length n bvec, and an n by n matrix Mmat. A list generated by fitfvbm is also sufficient.

Value

A list containing 4 objects: a vector containing the z-scores corresponding to the bias parameters bvec_z, a vector containing the p-values corresponding to the bias parameters bvec_p, a matrix containing the z-scores corresponding to the interaction parameters Mmat_z, and a matrix containing the standard errors corresponding to the interaction parameters Mmat_p.

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


Examples

```r
# Generate num=1000 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 1000; bvec <- c(0,0.5,0.25); Mmat <- matrix(0.1,3,3) - diag(0.1,3,3);
data <- rfvbm(num,bvec,Mmat)
# Fit a fully visible Boltzmann machine to data, starting from parameters bvec and Mmat.
model <- fitfvbm(data,bvec,Mmat)

#Propose a null hypothesis model
nullmodel <- list(bvec = c(0,0,0), Mmat = matrix(0,3,3))
```
marginpfvbm

Marginal probability function for a fully-visible Boltzmann machine.

Description

Computes the marginal probabilities (for values = +1 in each coordinate) under some specified bias vector and interaction matrix, specified by bvec and Mmat, respectively.

Usage

marginpfvbm(bvec, Mmat)

Arguments

bvec Vector of length n containing real valued bias parameters.
Mmat Symmetric n by n matrix, with zeros along the diagonal, containing the interaction parameters.

Value

Vector of length n containing the marginal probabilities of +1 in each coordinate.

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


Examples

# Compute z-scores
fvbmtests(data, model, nullmodel)

# Compute the marginal probabilities under bvec and Mmat.
# Set the parameter values
bvec <- c(0.05, 0.25)
Mmat <- matrix(0.1, 3, 3) - diag(0.1, 3, 3)
marginpfvbm(bvec, Mmat)
pfvbm

Probability mass function of a fully-visible Boltzmann machine evaluated for an individual vector.

Description

Compute the probability of a string of \( n \geq 1 \) binary spin variables (i.e. each element is -1 or 1) arising from a fully-visible Boltzmann machine with some specified bias vector and interaction matrix.

Usage

\[
\text{pfvbm}(xval, \text{bvec, Mmat})
\]

Arguments

- **xval**: Vector of length \( n \) containing binary spin variables.
- **bvec**: Vector of length \( n \) containing real valued bias parameters.
- **Mmat**: Symmetric \( n \) by \( n \) matrix, with zeros along the diagonal, containing the interaction parameters.

Value

The probability of the random string \( xval \) under a fully-visible Boltzmann machine with bias vector \( bvec \) and interaction matrix \( Mmat \).

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


Examples

\[
\text{# Compute the probability of the vector } xval = (-1, 1, -1), \text{ under bvec and Mmat.}
\]
\[
xval <- \text{c(-1, 1, -1)}
\]
\[
bvec <- \text{c(0, 0.5, 0.25)}
\]
\[
Mmat <- \text{matrix(0, 3, 3) - diag(0, 3, 3)}
\]
\[
\text{pfvbm(xval, bvec, Mmat)}
\]
Random data generation from a fully-visible Boltzmann machine.

Description

Generate N random strings of n>1 binary spin variables (i.e. each element is -1 or 1) arising from a fully-visible Boltzmann machine with some specified bias vector and interaction matrix.

Usage

rfvbm(num, bvec, Mmat)

Arguments

num Number N of random strings to be generated.
bvec Vector of length n containing real valued bias parameters.
Mmat Symmetric n by n matrix, with zeros along the diagonal, containing the interaction parameters.

Value

An N by n matrix, where each row contains a random spin variable string from a fully-visible Boltzmann machine with bias vector bvec and interaction matrix Mmat.

Note

The function allpfvbm must be called each time this function is run. Thus, it is much more efficient to generate N strings all at once, than to generate strings one at a time.

Author(s)

Andrew T. Jones and Hien D. Nguyen

References


Examples

# Generate num=10 random strings of n=3 binary spin variables under bvec and Mmat.
num <- 10
bvec <- c(0,0.5,0.25)
Mmat <- matrix(0.1,3,3) - diag(0.1,3,3)
rfvbm(num,bvec,Mmat)
Description
A dataset containing voting data from the first sitting of the Senate of the 45th Australian Parliament, until the final sitting of the year 2016. The first division during this period was conducted on the 31st of August 2016, and the last division was performed on the 1st of December 2016. In total, 147 divisions were performed during this period.

Each row represents a division (vote), each column is a party or independent. Data is either "Yes" or "No" depending on the vote. Absences and abstentions are left as NA. See https://hal.archives-ouvertes.fr/hal-01927188v1 for details of data preparation.

Usage

data(senate)

Format
A data frame with 147 rows (votes) and 9 variables (parties).

Author(s)
Jessica J. Bagnall

Source

Examples

dim(senate)
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