Package ‘r.jive’

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Title Perform JIVE Decomposition for Multi-Source Data

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Description Performs the JIVE decomposition on a list of data sets when the data share a dimension, returning low-rank matrices that capture the joint and individual structure of the data [O'Connell, MJ and Lock, EF (2016) <doi:10.1093/bioinformatics/btw324>]. It provides two methods of rank selection when the rank is unknown, a permutation test and a BIC selection algorithm. Also included in the package are three plotting functions for visualizing the variance attributed to each data source: a bar plot that shows the percentages of the variability attributable to joint and individual structure, a heatmap that shows the structure of the variability, and principal component plots.

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Perform JIVE Decompositions for Multi-Source Data

Description

Performs the JIVE decompositions on a list of data sets when the data share a dimension, returning low-rank matrices that capture the joint and individual structure of the data. It provides two methods of rank selection when the rank is unknown, a permutation test and a BIC selection algorithm. Also included in the package are three plotting functions for visualizing the variance attributed to each data source: a bar plot that shows the percentages of the variability attributable to joint and individual structure, a heatmap that shows the structure of the variability, and principal component plots.

Details

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License: GPL-3

Author(s)

Michael J. O’Connell and Eric F. Lock
Maintainer: Michael J. O’Connell <oconn725@umn.edu>

References

Examples

```r
## Not run:
set.seed(10)
# Load data that were simulated as in section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimData)
# Using default method ("perm")
Results <- jive(SimData)
summary(Results)

# Using BIC rank selection
BIC_result <- jive(SimData, method="bic")
summary(BIC_result)

## End(Not run)
## Load the permutation results
data(SimResults)
# Visualize results
showVarExplained(Results)
# showVarExplained is also called by the "jive" S3 class default plot method

# show heatmaps
showHeatmaps(Results)

# show PCA plots
showPCA(Results,1,c(1,1))
```

---

**BRCA Data**

**BRCA TCGA Dataset**

**Description**

These data were obtained from the data freeze for The Cancer Genome Atlas flagship BRCA publication (Cancer Genome Atlas Network, 2013), and processed as described in Lock and Dunson, 2013. Gene expression, methylation, and miRNA data are provided for 348 BRCA tumor samples.

**Usage**

`data(BRCA_data)`

**Format**

This dataset is a list of three entries for three different molecular sources:

- `Data[[1]]` (Data$Expression): gene expression matrix for 654 genes (rows) and 348 samples (columns)
- `Data[[2]]` (Data$Methylation): DNA methylation matrix for 574 cg sites (rows) and 348 samples (columns)
• Data[[3]] (Data$miRNA): miRNA expression matrix for 423 cg sites (rows) and 348 samples (columns).

The 348 columns are shared by the data sources (here, they correspond to tumor samples)

References


jive

JIVE Decomposition for Multi-source Data

Description

Given a list of linked data sets, this algorithm will return low-rank matrices of joint and individual structure. The jive function is a wrapper that centers and scales the data, replaces the missing values using SVDmiss (package SpatioTemporal) if necessary, then proceeds with a specified rank selection method. The jive.iter function performs the JIVE decomposition, given ranks and the processed data set. The functions jive.perm and bic.jive perform rank selection using a permutation test and the Bayesian Information Criterion, respectively.

Usage

jive(data, rankJ = 1, rankA = rep(1, length(data)), method = "perm",
    dnames = names(data), conv = "default", maxiter = 1000, scale = TRUE, center = TRUE,
    orthIndiv = TRUE, est = TRUE, showProgress=TRUE)

jive.iter(data, rankJ = 1, rankA = rep(1, length(data)), conv = 1e-06,
    maxiter = 1000, orthIndiv = TRUE, showProgress=TRUE)

jive.perm(data, nperms = 100, alpha = 0.05, est = TRUE, conv = 1e-06,
    maxiter = 1000, orthIndiv = TRUE, showProgress=TRUE)

bic.jive(data, n = unlist(lapply(data, ncol)) * unlist(lapply(data, nrow)),
    d = unlist(lapply(data, nrow)), conv = 1e-06, maxiter = 1000,
    orthIndiv = TRUE, showProgress=TRUE)

Arguments

data A list of two or more linked data matrices on which to perform the JIVE decomposition. These matrices must have the same column dimension, which is assumed to be common.
rankJ An integer giving the joint rank of the data, if known. If not given, this will be calculated using the chosen method. If the method is "given" then the default is 1.

rankA A vector giving the individual ranks of the data, if known. If not given, this will be calculated using the chosen method. If the method is "given" then the default is rep(1, length(data)).

method A string with the method to use for rank selection. Possible options are "given", "perm", and "bic". The default is "perm". If ranks are known, you should use "given".

dnames A vector containing the names of the data sources. Default is names(data).

conv A value indicating the convergence criterion.

maxiter The maximum number of iterations for each instance of the JIVE algorithm.

scale A boolean indicating whether or not the data should be scaled. If TRUE, each data set is divided by its Frobenius norm prior to the JIVE algorithm. Default is TRUE.

center A boolean indicating whether or not the data should be centered. If TRUE, the rows of each data set are mean-centered. Default is TRUE.

orthIndiv A boolean indicating whether or not the algorithm should enforce orthogonality between individual structures. The default is TRUE.

est A boolean indicating whether or not the data should first be compressed via singular value decomposition before running the JIVE algorithm; this will yield identical results, but can improve computational efficiency dramatically for data with more rows than columns. The default is TRUE.

showProgress A boolean indicating whether or not to give output showing the progress of the algorithm. If TRUE, the algorithm will print out updates about the number of iterations the algorithm is taking and the progress of the rank selection method, if applicable. If FALSE, the algorithms will give no printed output when run.

nperms A value indicating the number of permutations for rank estimation. Default is 100.

alpha A value between 0 and 1 giving the quantile to use for rank estimation. Default is .05.

n A vector for the total number of entries in each data source, for use in the BIC calculation. The default is to calculate the total number of entries in each element of data.

d A vector for the total number of variables (rows) in each data source, for use in the BIC calculation. The default is to calculate the number of rows in each element of data.

Details

It is recommended to make all calls to the JIVE functions using the jive() wrapper, as this function does all of the pre-processing of the data (centering, scaling, handling missingness, and reducing the data set to increase computational efficiency). The algorithm will print the number of iterations for each call of the JIVE iteration function.
Value

Returns an object of class jive.

data a list containing the centered and scaled data sets, with missing values replaced, if applicable.
joint a list containing matrices that capture the joint structure of the data.
individual a list containing matrices that capture the individual structure of the data.
rankJ a value giving joint rank of the data.
rankA a vector giving the individual ranks of the data.
method a string denoting the rank selection method used.
bic.table if bic rank selection used, a matrix that shows the BIC values for different ranks.
converged if permutation rank selection used, a boolean stating whether or not the rank selection converged within the maximum number of iterations.
scale A list of four elements: $Center and $Scale are booleans stating whether the data were centered or scaled, respectively, $‘Center Values’ gives the value subtracted from each row and $‘Scale Values’ gives the multiplicative scale factor for each source.

Author(s)

Michael J. O’Connell and Eric F. Lock

References


See Also

summary.jive, plot.jive

Examples

```r
## Not run:
set.seed(18)
# Load data that were simulated as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimData)
# Using default method ("perm")
Results <- jive(SimData)
summary(Results)
```
jive.predict

Predict JIVE scores for new data

Description

Computes JIVE scores for new data via iterative least squares, with fixed loadings given by a previous JIVE analysis.

Usage

jive.predict(data.new, jive.output)

Arguments

data.new A list of two or more linked data matrices on which to estimate JIVE scores. These matrices must have the same column dimension N, which is assumed to be common.

jive.output An object of class "jive", with row dimensions matching those for data.new.

Value

joint.scores r X N matrix of joint scores
individual.scores List where entry [[ij]] gives the r_i X N matrix of individual scores for source i
errors Vector of the proportion of total variance explained over iterations during estimation
joint.load d X r matrix of joint loadings
indiv.load List where entry [[ij]] gives the d_i X N matrix of individual loadings for source i

Author(s)

Adam Kaplan

References

pjsum

See Also
jive

Examples

```r
# Load data that were simulated as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimData)
# load JIVE results (using default settings) for simulated data
data(SimResults)
# predict JIVE scores for data (treated as "new data" here)
pred.results <- jive.predict(SimData,Results)
# estimated joint structure is pred.results$joint.load %>% pred.results$joint.scores
# estimated individual structure for source i is
# pred.results$indiv.load[[i]] %>% pred.results$indiv.scores[[i]]
```

pjsum

Calculate Number of Free Parameters for BIC Calculation

Description

Computes the number of free parameters from the individual structure of the data. Used internally to calculate the BIC for the JIVE decomposition.

Usage

`pjsum(dim, rank)`

Arguments

- `dim` A vector containing the number of rows of each data source.
- `rank` A vector containing the ranks of the individual structure.

Value

Returns the number of free parameters.

Author(s)

Michael J. O’Connell and Eric F. Lock

Examples

```r
pjsum(c(25,50), c(1,2))
```
Create Plots for a JIVE Object

Description

Three types of plots are available. By default (or `type="var"`), this creates a bar plot showing the percentage of variability attributable to joint structure, individual structure, and residual variance. With `type="heat"`, it will create a series of heatmaps. With `type="pca"`, it will give principal component plots.

Usage

```r
## S3 method for class 'jive'
plot(x, type="var", ...)
```

Arguments

- `x`: An object of class "jive" to be plotted.
- `type`: A string indicating the type of plot. The default, "var", generates a bar plot of the variance explained, "heat" generates a heatmap, and "pca" generates principal component plots.
- `...`: Additional arguments to pass to the specific plotting functions. See documentation for `showVarExplained`, `showHeatmaps`, and `showPCA` for more details.

Author(s)

Michael J. O'Connell and Eric F. Lock

References


See Also

`showVarExplained`, `showHeatmaps`, `showPCA`

Examples

```r
# Load JIVE results (using default settings) for simulated data
# as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimResults)
# Visualize results
```
show.image

# Bar plot of variation explained
plot(Results)

# Heatmap
plot(Results,type="heat")

# Principal components plots
plot(Results,type="pca",1,c(1,1))

---

show.image  

**Draw a Heatmap from a Matrix**

**Description**

Given a matrix, this function draws a heatmap. This function is used internally by the showHeatmaps function.

**Usage**

`show.image(Image, ylab = "")`

**Arguments**

- **Image**  
  A matrix for which to create the heatmap.
- **ylab**  
  A string for the y-label of the plot.

**Author(s)**

Michael J. O'Connell and Eric F. Lock

**References**


**See Also**

`showHeatmaps.jive`, `plot.jive`
**showHeatmaps**

*Heatmaps for JIVE Decompositions*

**Description**

This function draws heatmaps for the components of a JIVE decomposition.

**Usage**

```r
showHeatmaps(result, order_by = 0, show_all = TRUE)
```

**Arguments**

- `result`: An object of class "jive".
- `order_by`: Specifies how to order the rows and columns of the heatmap. If `order_by=-1`, the matrices are not re-ordered. If `order_by=0`, orderings are determined by joint structure. Otherwise, `order_by` gives the number of the individual structure dataset to determine the ordering. In all cases orderings are determined by complete-linkage hierarchical clustering of Euclidean distances.
- `show_all`: Specifies whether to show the full decomposition of the data, JIVE estimates, and noise. If `show_all=FALSE`, only the matrix (or matrices) that determined the column ordering is shown.

**Details**

The columns correspond to the shared dimension (for example, a common sample set), and the ordering of the columns is the same for all matrices shown.

**Author(s)**

Michael J. O’Connell and Eric F. Lock

**References**


**See Also**

- `jive`, `plot.jive`, `show.image`
Examples

```r
# Load JIVE results (using default settings) for simulated data
# as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimResults)
# Display the heatmaps (may need to fiddle with plot window dimensions for this to appear well)
showHeatmaps(SimResults)
# Order by first data set individual structure
showHeatmaps(SimResults, order_by=1)
# Show only joint structure
showHeatmaps(SimResults, show_all=FALSE)
```

### showPCA

**Principal Component Plots for JIVE Decomposition**

**Description**

Display principal component plots of the joint and individual structure of a data set after a JIVE decomposition.

**Usage**

```r
showPCA(result, n_joint = 0, n_indiv = rep(0, length(result$data)),
          Colors = "black", pch=1)
```

**Arguments**

- `result` 
  An object of class "jive".
- `n_joint` 
  The number of joint components to plot.
- `n_indiv` 
  The vector of the number of individual components to plot for each data set.
- `Colors` 
  The colors of the data points in the plot. Can be a vector specifying a different color for each sample.
- `pch` 
  Character to use for plotting. Can be a vector specifying a different character for each sample.

**Details**

This shows the patterns in the column space that maximize variability of joint or individual structure, analogous to principal components. A multi-panel figure with aligned scatterplots for each pair of principal components, across both joint and individual structure, will be generated. Plotted points correspond to shared columns (e.g., samples).

**Author(s)**

Michael J. O’Connell and Eric F. Lock
showVarExplained

References

See Also
jive, plot.jive

Examples
###Load JIVE results (using default settings) for simulated data
###as in Section 2.4 of Lock et al., 2013,
###with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimResults)
# Visualize results
# Plot the three components, 1 joint and 1 individual from each source
showPCA(Results,1,c(1,1))
###This displays three scatterplots:
#the first joint principal component vs. the first principal component individual to source 1,
#the first joint component vs. the first component individual to source 2, and
#the first component individual to source 1 vs. the first component individual to source 2.

---

showVarExplained  

Description
Creates a bar plot displaying the variance explained from a JIVE decomposition. Shows the percentage of variance attributed to each of joint structure, individual structure, and residual variance.

Usage
showVarExplained(result, col = c("grey20", "grey43", "grey65"))

Arguments

- result: An object of class "jive".
- col: A vector for the colors of the bars in the plot.

Author(s)
Michael J. O'Connell and Eric F. Lock
References


See Also

plot.jive

Examples

# Load JIVE results (using default settings) for simulated data
# as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimResults)
# Visualize results
showVarExplained(Results)
# showVarExplained is also called by the "jive" S3 class default plot method
plot(Results)

SimData

Simulated Dataset

Description

These data were simulated as described in Section 2.4 of Lock et al., 2013. There are two simulated sources, with rank 1 joint structure and rank 1 structure individual to each source.

Usage

data(SimData)

Format

This dataset is a list of two entries:

- Data[[1]] (Data$Data1): 50 variables (rows) and 100 samples (columns)
- Data[[2]] (Data$Data2): 50 variables (rows) and 100 samples (columns)

The 100 columns are shared by the sources.

References


SimResults

### JIVE Results for Simulated Dataset

**Description**

JIVE results for the simulated data SimData, which were simulated as described in Section 2.4 of Lock et al., 2013. There are two simulated sources, with rank 1 joint structure and rank 1 structure individual to each source. These results are obtained by running JIVE with permutation testing to select the ranks, and other defaults.

**Usage**

```r
data(SimResults)
```

**Format**

Results: an object of class `jive`.

**References**


---

### Summarize a JIVE Decomposition

**Description**

Provides a summary of JIVE output. Displays the method used for rank selection, the chosen ranks, and a table of the proportion of variance attributable to joint structure, individual structure, and residual variance. `print.jive` only displays the variance table.

**Usage**

```r
## S3 method for class 'jive'
summary(object, ...)

## S3 method for class 'jive'
print(x, ...)```
Arguments

object An object of class "jive".
x An object of class "jive".
... Additional arguments.

Value

Returns a list.

Method a string containing the method used for rank selection.
Ranks the method used for rank selection.
Variance the method used for rank selection.

Author(s)

Michael J. O'Connell and Eric F. Lock

References


See Also

jive

Examples

```r
# Load JIVE results (using default settings) for simulated data
# as in Section 2.4 of Lock et al., 2013,
# with rank 1 joint structure, and rank 1 individual structure for each dataset
data(SimResults)

# Summary method
summary(Results)

# Print method
Results
```
svdwrapper

Wrapper Function to Perform SVD

Description
Performs SVD on a data matrix using the base svd() function in R, with a workaround to avoid LAPACK errors. If an SVD of the data matrix gives an error, an SVD of its transpose will be performed. Used internally when computing the JIVE decomposition. Credit to Art Owen: \url{https://stat.ethz.ch/pipermail/r-help/2007-October/143508.html}.

Usage
svdwrapper(x, nu, nv, verbose=F)

Arguments
- x: a numeric matrix whose SVD decomposition is to be computed.
- nu: the number of left singular vectors to be computed.
- nv: the number of right singular vectors to be computed.
- verbose: logical. Print error message if needed.

Value
An svd object, as returned by svd(x,nu=nu,nv=nv).

Author(s)
Michael J. O'Connell and Eric F. Lock

Examples
x <- matrix(rnorm(100),nrow=10,ncol=10)
SVD = svdwrapper(x,nu=1,nv=1)
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