

Package ‘tensorMam’

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Type Package

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Description A tensor Estimation approach to multivariate additive models. The B-splines are used to approximate unknown function. The number of predictors can be diverged as sample size increases, in which the penalty LASSO, MCP or SCAD can be used.

License GPL (>= 2)

Imports splines, Rcpp (>= 0.11.15), RcppEigen (>= 0.3.2.3.0)

LinkingTo Rcpp, RcppEigen

RoxygenNote 6.0.1

NeedsCompilation yes

Repository github

URL <https://github.com/xliusufe/tensorMam>

Encoding UTF-8

R topics documented:

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| | |
|-------------------|---|
| tensorMam-package | <i>A tensor estimation approach to multivariate additive models</i> |
|-------------------|---|

Description

For a high-dimensional multivariate additive model (MAM) using B-splines, with or without aparsity assumptions, treating the coefficients as a third-order tensor and borrowing Tucker decomposition to reduce the number of parameters. The multivariate sparse group lasso (mcp or scad) and the coordinate descent algorithm are used to estimate functions for sparsity situation.

Details

This section should provide a more detailed overview of how to use the package, including the most important functions.

Author(s)

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References

A tensor estimation approach to multivariate additive models.

| | |
|------------|--|
| breastData | <i>Breast cancer gene expression and DNA copy number dataset</i> |
|------------|--|

Description

The breast cancer dataset includes gene expressions and comparative genomic hybridization measurements for 89 subjects, which is from Chin et al. (2006). This dataset has been considered by Witten et al. (2009) and Chen et al. (2013). In our paper, we selected chromosome 21, including $q = 44$ variables for copy-number variations and $p = 227$ variables for gene expression. As in Chen et al. (2013), we consider copy-number variations as the responses and gene expressions as the predictors.

Usage

```
data(breastData)
```

Details

The "breastData" is formatted as a list with elements:

| | |
|------------|--|
| dna: | the CGH spots , a matrix with size 2149×89 and the sample size 89 |
| rna: | genes, a matrix with size 19672×89 and the sample size 89 |
| chrom: | chromosomal location of each CGH spot, a 2149-vector |
| nuc: | nucleotide position of each CGH spot, a 2149-vector |
| gene: | an accession number for each gene, a 19672-vector |
| genenames: | gene name, a 19672-vector |

genechr: chromosomal location of each gene, a 19672-vector
 genedesc: description of each gene, a 19672-vector
 genepos: nucleotide position of each gene, a 19672-vector

References

Chin, K., DeVries, S., Fridlyand, J., Spellman, P., Roydasgupta, R., Kuo, W.-L., Lapuk, A., Neve, R., Qian, Z., Ryder, T., Chen, F., Feiler, H., Tokuyasu, T., Kingsley, C., Dairkee, S., Meng, Z., Chew, K., Pinkel, D., Jain, A., Ljung, B., Esserman, L., Albertson, D., Waldman, F. & Gray, J. (2006). Genomic and transcriptional aberrations linked to breast cancer pathophysiologies. *Cancer cell* **10** (6), 429-541.

Witten, D. M., Tibshirani, R. and Hastie, T. (2009). A penalized matrix decomposition, with applications to sparse principal components and canonical correlation analysis. *Biostatistics* **10** (3), 515-534.

Chen, K., Dong, H., and Chan, K. S. (2013). Reduced rank regression via adaptive nuclear norm penalization. *Biometrika*, **100** (4), 901-920.

Examples

```
data(breastData)
attach(breastData)
Y = t(dna[chrom==21,])
Xt = t(rna[which(genechr==21),])
n = nrow(Y)

minX = apply(Xt,2,min)
maxX = apply(Xt,2,max)
X = (Xt - matrix(rep(minX,each = n),n))/matrix(rep(maxX-minX,each = n),n)
Y = scale(Y)
fit <- mam_sparse_dr(Y[,1:5], X[,1:10])
D3hat <- fit$Dnew
opt <- fit$rk_opt
detach(breastData)
```

| | |
|--------------|--------------------------------------|
| generateData | <i>Generate data from MAM model.</i> |
|--------------|--------------------------------------|

Description

Generate data for a high-dimensional multivariate additive model, with or without aparsity assumptions.

Usage

```
generateData(n, q, p, s, D2, sigma2=NULL, indexF=NULL, seed_id=NULL)
```

Arguments

| | |
|---------|---|
| n | Sample size. |
| q | The number of responses, $q \geq 1$. |
| p | The number of covariates, $p \geq 1$. |
| s | The true covariates associating to response, $s \geq 1$. |
| D2 | The mode of unfolding $D_{(2)}$. |
| sigma2 | err variance. Default is 0.1. |
| indexF | A $q \times s$ matrix. The index of significant predictors corresponding to response y_i . Default is the matrix with each row being $(1, 2, \dots, s)$. |
| seed_id | A positive integer, the seed for generating the random numbers. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. We choose r_1 , r_2 and r_3 by BIC or CV.

Value

| | |
|----|--|
| Y | Response, a $n \times q$ -matrix. |
| X | Design matrix, a $n \times p$ -matrix. |
| f0 | True functions. |

References

A tensor estimation approach to multivariate additive models.

See Also

mam_sparse

Examples

```
# Example 1

D2 <- matrix(runif(30, 0.7, 1), 2, 15)
mydata <- generateData(200, 3, 5, 5, D2)

Y <- mydata$Y
X <- mydata$X


# Example 2
n <- 500
p <- 10
q <- 10
s <- 10
K <- 6
s0 <- s
r10=r20=r30=2
S3 <- matrix(runif(r10*r20*r30,3,7),nrow = r30)
T1 <- matrix(rnorm(s0*r10),nrow = s0)
U1 <- qr.Q(qr(T1))
```

```

T1 <- matrix(rnorm(K*r20),nrow = K)
U2 <- qr.Q(qr(T1))
T1 <- matrix(rnorm(q*r30),nrow = q)
U3 <- qr.Q(qr(T1))
D3 <- U3%*%S3%*%t(kronecker(U2,U1))
D2 <- TransferModalUnfoldings(D3,3,2,s0,K,q)
mydata <- generateData(n,q,p,s0,D2)

```

mam

*Fit MAM without sparsity assumption and with fixed ranks.***Description**

Fit a low-dimensional multivariate additive model using B-splines, without sparsity assumptions, and given ranks r_1, r_2, r_3 .

Usage

```

mam(Y, X, K = 6, r1 = NULL, r2 = NULL, r3 = NULL, SABC = NULL, degr = 3,
    eps = 1e-4, max_step = 20)

```

Arguments

| | |
|----------|--|
| Y | A $n \times q$ numeric matrix of responses. |
| X | A $n \times p$ numeric design matrix for the model. |
| K | The number of B-spline base function, that is the plus of both degrees of base function and the number of knots. Default is 6. |
| degr | the number of knots of B-spline base function. Default is 3. |
| r1 | The first dimension of single value matrix of the tensor. Default is 2. |
| r2 | The second dimension of single value matrix of the tensor. Default is 2. |
| r3 | The third dimension of single value matrix of the tensor. Default is 2. |
| SABC | A user-specified list of initial coefficient matrix of S, A, B, C . By default, initial matrices are provided by random. |
| eps | Convergence threshold. The algorithm iterates until the relative change in any coefficient is less than eps. Default is $1e-4$. |
| max_step | Maximum number of iterations. Default is 20. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. We choose r_1, r_2 and r_3 by BIC or CV.

Value

| | |
|------|---|
| Dnew | Estimator of $D_{(3)}$. |
| rss | Residual sum of squares (RSS). |
| Y | Response Y . |
| X | Design matrix X . |
| Z | Design matrix of Bspline approximation. |

References

A tensor estimation approach to multivariate additive models.

See Also

mam_sparse

Examples

```
D2 <- matrix(runif(50, 0.7, 1), 2, 25) # tensor with size 5*2*5
mydata <- generateData(200, 5, 5, 5, D2)

fit <- mam(mydata$Y, mydata$X)
D3hat <- fit$Dnew
D2hat <- TransferModalUnfoldings(D3hat,3,2,5,2,5)
```

| | |
|--------|---|
| mam_dr | <i>Fit MAM without sparsity assumption, and with ranks selected by BIC or CV.</i> |
|--------|---|

Description

Fit a low-dimensional multivariate additive model using B-splines, without sparsity assumptions, and with ranks r_1, r_2, r_3 selected by BIC or CV.

Usage

```
mam_dr(Y, X, method = "BIC", ncv = 10, K_index = NULL, r1_index = NULL,
       r2_index = NULL, r3_index = NULL, SABC = NULL, degr = 3, eps = 1e-4,
       max_step = 20)
```

Arguments

| | |
|----------|--|
| Y | A $n \times q$ numeric matrix of responses. |
| X | A $n \times p$ numeric design matrix for the model. |
| method | The method to be applied to select parameters. Either "BIC" (the default), or "CV". |
| ncv | The number of cross-validation folds. Default is 10. If method is "BIC", ncv is useless. |
| K_index | A user-specified sequence of K values, where K is the number of B-spline base function. Default is k_index=6. |
| r1_index | A user-specified sequence of r_1 values, where r_1 is the first dimension of single value matrix of the tensor. Default is $r1_index = 1, \dots, \min(\log(n), p)$. |
| r2_index | A user-specified sequence of r_2 values, where r_2 is the second dimension of single value matrix of the tensor. Default is $r2_index = 1, \dots, \max\{K_index\}$. |
| r3_index | A user-specified sequence of r_3 values, where r_3 is the third dimension of single value matrix of the tensor. Default is $r3_index = 1, \dots, \min(\log(n), q)$. |
| SABC | A user-specified list of initial coefficient matrix of S, A, B, C , which is a list with values S, A, B, C . By default, initial matrices are provided by random. |

| | |
|----------|---|
| degr | the number of knots of B-spline base function. Default is 3. |
| eps | Convergence threshold. The algorithm iterates until the relative change in any coefficient is less than eps. Default is 1e-4. |
| max_step | Maximum number of iterations. Default is 20. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. We choose r_1 , r_2 and r_3 by BIC or CV.

Value

| | |
|----------|--|
| Dnew | Estimator of $D_{(3)}$. |
| rss | Residual sum of squares (RSS). |
| rk_opt | The optimal parametres that slected by BIC or CV. It is a vector with length 4, which are selected r_1 , r_2 , r_3 , and K . |
| selected | Which λ is selection. |
| Y | Response Y . |
| X | Design matrix X . |
| Z | Design matrix of Bspline approximation. |

References

A tensor estimation approach to multivariate additive models.

See Also

mam, mam_sparse_dr

Examples

```
D2 <- matrix(runif(50, 0.7, 1), 2, 25) # tensor with size 5*2*5
mydata <- generateData(200, 5, 5, 5, D2)

fit <- mam_dr(mydata$Y, mydata$X)
D3hat <- fit$Dnew
D2hat <- TransferModalUnfoldings(D3hat,3,2,5,2,5)
opt <- fit$rk_opt
```

mam_sparse

Fit MAM with sparsity assumption and fixed ranks.

Description

Fit a high-dimensional multivariate additive model using B-splines, with or without aparsity assumptions, and given ranks given ranks r_1 , r_2 , r_3 . The multivariate sparse group lasso (mcp or scad) and the coordinate descent algorithm are used to estimate functions for sparsity situation.

Usage

```
mam_sparse(Y, X, K = 6, r1 = NULL, r2 = NULL, r3 = NULL, method="BIC", ncv=10,
  penalty="LASSO", isPenColumn=TRUE, lambda = NULL, SABC = NULL, degr = 3,
  nlam = 20, lam_min = 1e-3, eps1 = 1e-4, maxstep1 = 20, eps2 = 1e-4,
  maxstep2 = 20, gamma = 2, dfmax = NULL, alpha = 1)
```

Arguments

| | |
|-------------|--|
| Y | A $n \times q$ numeric matrix of responses. |
| X | A $n \times q$ numeric design matrix for the model. |
| K | The number of B-spline base function, that is the plus of both degrees of base function and the number of knots. Default is 7. |
| degr | The number of knots of B-spline base function. Default is 3. |
| r1 | The first dimension of single value matrix of the tensor. Default is 2. |
| r2 | The second dimension of single value matrix of the tensor. Default is 2. |
| r3 | The third dimension of single value matrix of the tensor. Default is 2. |
| method | The method to be applied to select parameters. Either "BIC" (the default), or "CV". |
| ncv | The number of cross-validation folds. Default is 10. If method is BIC, ncv is useless. |
| penalty | The penalty to be applied to the model. Either "LASSO" (the default), "SCAD", or "MCP". |
| isPenColumn | A logical value indicating whether the coefficients associating with X_j that affects whole response y is penalized. Default is TRUE. If isPenColumn is TRUE, the coefficients associating with X_j that affects simultaneously whole response y is penalized for each $j \in \{1, \dots, p\}$. If isPenColumn is FALSE, the coefficients associating with X_j that affects single response y_l is penalized for each $j \in \{1, \dots, p\}$, where $l \in \{1, \dots, q\}$. |
| lambda | A user-specified sequence of lambda values. By default, a sequence of values of length nlam is computed, equally spaced on the log scale. |
| SABC | A user-specified list of initial coefficient matrix of S, A, B, C . By default, initial matrices are provided by random. |
| nlam | The number of lambda values. Default is 20. |
| lam_min | The smallest value for lambda, as a fraction of lambda.max. Default is 1e-3. |
| eps1 | Convergence threshold. The algorithm iterates until the relative change in any coefficient is less than eps1. Default is 1e-4. |
| maxstep1 | Maximum number of iterations. Default is 20. |
| eps2 | Convergence threshold. The Coordinate descent method algorithm iterates until the relative change in any coefficient is less than eps2. Default is 1e-4. |
| maxstep2 | The maximum iterates number of coordinate descent method. Default is 20. |
| gamma | The tuning parameter of the MCP/SCAD penalty (see details). |
| dfmax | Upper bound for the number of nonzero coefficients. Default is no upper bound. However, for large data sets, computational burden may be heavy for models with a large number of nonzero coefficients. |
| alpha | Tuning parameter for the Mnet estimator which controls the relative contributions from the LASSO, MCP/SCAD penalty and the ridge, or L2 penalty. alpha=1 is equivalent to LASSO, MCP/SCAD penalty, while alpha=0 would be equivalent to ridge regression. However, alpha=0 is not supported; alpha may be arbitrarily small, but not exactly 0. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. r_1 , r_2 and r_3 are fixed.

Value

| | |
|------------|--|
| betapath | Solution path of β . |
| rss | Residual sum of squares (RSS). |
| df | Degrees of freedom. |
| lambda | The sequence of regularization parameter values in the path. |
| lambda_opt | The value of lambda with the minimum BIC value. |
| selectedID | The index of lambda corresponding to lambda_opt. |
| activeA | The active set. |
| Dnew | Estimator of $D_{(3)}$. |
| Y | Response Y . |
| X | Design matrix X . |
| Z | Design matrix of Bspline approximation λ . |

References

A tensor estimation approach to multivariate additive models.

See Also

mam, mam_sparse_dr

Examples

```
D2 <- matrix(runif(50, 0.7, 1), 2, 25) # tensor with size 5*2*5
mydata <- generateData(200, 5, 10, 5, D2)

fit <- mam_sparse(mydata$Y, mydata$X)
D3hat <- fit$Dnew
D2hat <- TransferModalUnfoldings(D3hat,3,2,5,2,5)
```

mam_sparse_dr

Fit MAM with sparsity assumption and ranks selected by BIC or CV.

Description

Fit a high-dimensional multivariate additive model using B-splines, with or with aparsity assumptions and ranks selected by BIC or CV. The multivariate sparse group lasso (mcp or scad) and the coordinate descent algorithm are used to estimate functions for sparsity situation. The tuning parameter is selected by BIC or CV, which matches the method of rank selection.

Usage

```
mam_sparse_dr(Y, X, method = "BIC", ncv = 10, penalty = "LASSO", isPenColumn=TRUE,
              K_index = NULL, r1_index = NULL, r2_index = NULL, r3_index = NULL,
              lambda = NULL, SABC = NULL, nlam = 50, degr = 3, lam_min = 0.01,
              eps1 = 1e-4, maxstep1 = 20, eps2 = 1e-4, maxstep2 = 20, gamma = 2,
              dfmax = NULL, alpha = 1)
```

Arguments

| | |
|-------------|--|
| Y | A $n \times q$ numeric matrix of responses. |
| X | A $n \times q$ numeric design matrix for the model. |
| method | The method to be applied to select parameters. Either "BIC" (the default), or "CV". |
| ncv | The number of cross-validation folds. Default is 10. If method is BIC, ncv is useless. |
| penalty | The penalty to be applied to the model. Either "LASSO" (the default), "SCAD", or "MCP". |
| isPenColumn | A logical value indicating whether the coefficients associating with X_j that affects whole response y is penalized. Default is TRUE. If isPenColumn is TRUE, the coefficients associating with X_j that affects simultaneously whole response y is penalized for each $j \in \{1, \dots, p\}$. If isPenColumn is FALSE, the coefficients associating with X_j that affects single response y_l is penalized for each $j \in \{1, \dots, p\}$, where $l \in \{1, \dots, q\}$. |
| K_index | A user-specified sequence of K values, where K is the number of B-spline base function. Default is k_index=6. |
| r1_index | A user-specified sequence of r_1 values, where r_1 is the first dimension of single value matrix of the tensor. Default is r1_index= $1, \dots, \min(\lceil \log(n) \rceil, p)$. |
| r2_index | A user-specified sequence of r_2 values, where r_2 is the second dimension of single value matrix of the tensor. Default is r2_index= $1, \dots, \max\{K_index\}$. |
| r3_index | A user-specified sequence of r_3 values, where r_3 is the third dimension of single value matrix of the tensor. Default is r3_index= $1, \dots, \min(\lceil \log(n) \rceil, q)$. |
| lambda | A user-specified sequence of lambda values. By default, a sequence of values of length nlam is computed, equally spaced on the log scale. |
| SABC | A user-specified list of initial coefficient matrix of S, A, B, C . By default, initial matrices are provided by random. |
| nlam | The number of lambda values. Default is 50. |
| degr | The number of knots of B-spline base function. Default is degr = 3. |
| lam_min | The smallest value for lambda, as a fraction of lambda.max. Default is 1e-2. |
| eps1 | Convergence threshold. The algorithm iterates until the relative change in any coefficient is less than eps1. Default is 1e-4. |
| maxstep1 | Maximum number of iterations. Default is 20. |
| eps2 | Convergence threshold. The Coordinate descent method algorithm iterates until the relative change in any coefficient is less than eps2. Default is 1e-4. |
| maxstep2 | The maximum iterates number of coordinate descent method. Default is 20. |
| gamma | The tuning parameter of the MCP/SCAD penalty (see details). |

| | |
|-------|---|
| dfmax | Upper bound for the number of nonzero coefficients. Default is no upper bound. However, for large data sets, computational burden may be heavy for models with a large number of nonzero coefficients. |
| alpha | Tuning parameter for the Mnet estimator which controls the relative contributions from the LASSO, MCP/SCAD penalty and the ridge, or L2 penalty. $\alpha=1$ is equivalent to LASSO, MCP/SCAD penalty, while $\alpha=0$ would be equivalent to ridge regression. However, $\alpha=0$ is not supported; α may be arbitrarily small, but not exactly 0. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. We choose r_1 , r_2 and r_3 by BIC or CV.

Value

| | |
|------------|---|
| Dnew | Estimator of $D_{(3)}$. |
| rss | Residual sum of squares (RSS). |
| df | Degrees of freedom. |
| activeA | The active set. |
| lambda | The sequence of regularization parameter values in the path. |
| selectedID | The index of lambda corresponding to lambda_opt. |
| lambda_opt | The value of lambda with the minimum BIC or CV value. |
| RSS | The values of BIC or CV, which is a vector. |
| rk_opt | The optimal parameters that selected by BIC or CV. It is a vector with length 4, which are selected r_1 , r_2 , r_3 , and K . |
| Y | Response Y . |
| X | Design matrix X . |
| Z | Design matrix of Bspline approximation. |

References

A tensor estimation approach to multivariate additive models.

See Also

mam_dr, mam_sparse

Examples

```
#Example 1

D2 <- matrix(runif(50, 0.7, 1), 2, 25) # tensor with size 5*2*5
mydata <- generateData(200, 5, 10, 5, D2)

fit <- mam_sparse_dr(mydata$Y, mydata$X)
D3hat <- fit$Dnew
D2hat <- TransferModalUnfoldings(D3hat,3,2,5,2,5)
opt <- fit$rk_opt

#Example 2
```

```

data(breastData)
attach(breastData)
Y = t(dna[chrom==21,])
Xt = t(rna[which(genechr==21),])
n = nrow(Y)

minX = apply(Xt,2,min)
maxX = apply(Xt,2,max)
X = (Xt - matrix(rep(minX,each = n),n))/matrix(rep(maxX-minX,each = n),n)
Y = scale(Y)
fit <- mam_sparse_dr(Y[,1:5], X[,1:10])
D3hat <- fit$Dnew
opt <- fit$rk_opt
detach(breastData)

```

plotfuns

Plot the estimated curves from tensorMam.

Description

Plot the curves fitted by mam, mam_dr, mam_sparse, and mam_sparse_dr

Usage

```
plotfuns(fit, funTrueID, true.curve=FALSE)
```

Arguments

| | |
|------------|--|
| fit | Object outputting from mam, mam_dr, mam_sparse or mam_sparse_dr. |
| funTrueID | Which function to be plotted. It is a 2-vector. In MAM models, there are $s_0 \times q$ true functions. Thus, the first argument must be smaller than s_0 , and the second argument must be smaller than q . |
| true.curve | A Logical flag. Plot both true and estimated curves if true.curve=TRUE. Plot estimated curve only if true.curve=FALSE. Default is FALSE. |

Details

This function gives pq functional coefficients' estimators of MAM. The singular value matrix of tensor is a $r_1 \times r_2 \times r_3$ -tensor. We choose r_1 , r_2 and r_3 by BIC or CV.

References

A tensor estimation approach to multivariate additive models.

See Also

mam, mam_dr, mam_sparse, mam_sparse_dr

Examples

```

n <- 200
p <- 10
q <- 10
s <- 10
K <- 6
s0 <- s
r10=r20=r30=2
S3 <- matrix(runif(r10*r20*r30,3,7),nrow = r30)
T1 <- matrix(rnorm(s0*r10),nrow = s0)
U1 <- qr.Q(qr(T1))
T1 <- matrix(rnorm(K*r20),nrow = K)
U2 <- qr.Q(qr(T1))
T1 <- matrix(rnorm(q*r30),nrow = q)
U3 <- qr.Q(qr(T1))
D3 <- U3%*%S3%*%t(kronecker(U2,U1))
D2 <- TransferModalUnfoldings(D3,3,2,s0,K,q)
mydata <- generateData(n, q, p, s0, D2)
fit <- mam(mydata$Y, mydata$X)
fit$D2 <- D2
fit$s0 <- s0
fit$X0 <- matrix(runif(100*p),100,p)
plotfuns(fit, c(1,1))

```

TransferModalUnfoldings

Transfer a tensor's modal unfoldings to another.

Description

Transfer a tensor's modal unfoldings to another.

Usage

```
TransferModalUnfoldings(S, d1, d2 , r1, r2, r3)
```

Arguments

| | |
|----|---|
| S | A mode-d1-unfolding of a tensor with size $r_1 \times r_2 \times r_3$, input unfolding |
| d1 | An integer, the mode of unfolding $S_{(d_1)}$ |
| d2 | An integer, the mode of output unfolding $S_{(d_2)}$ |
| r1 | The first dimension of tensor |
| r2 | The second dimension of tensor |
| r3 | The third dimension of tensor |

Details

This function transfers an input mode-d1-unfolding $S_{(d_1)}$ to mode-d2-unfolding $S_{(d_2)}$

Value

D the output mode-d2-unfolding, $S_{(d_2)}$

References

A tensor estimation approach to multivariate additive models.

Examples

```
D1 <- matrix(1:24,nrow = 4) # A tensor unfolding with size 4*6  
D2 <- TransferModalUnfoldings(D1,1,2,4,3,2)
```

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