Package 'TensorTools'

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Type Package

Title Multilinear Algebra

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Maintainer Kyle Caudle <kyle.caudle@sdsmt.edu>

Description A set of tools for basic tensor operators. A tensor in the context of data analysis in a multidimensional array. The tools in this package rely on using any discrete transformation (e.g. Fast Fourier Transform (FFT)). Standard tools included are the Eigenvalue decomposition of a tensor, the QR decomposition and LU decomposition. Other functionality includes the inverse of a tensor and the transpose of a symmetric tensor. Functionality in the package is outlined in Kernfeld, E., Kilmer, M., and Aeron, S. (2015) <doi:10.1016/j.laa.2015.07.021>.

Imports methods,raster,png, wavethresh, gsignal, Matrix, matrixcalc

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Encoding UTF-8

LazyData true

LazyDataCompression xz

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RoxygenNote 7.3.2

Suggests knitr, rmarkdown

VignetteBuilder knitr

NeedsCompilation no

Author Kyle Caudle [aut, cre],
Randy Hoover [ctb],
Jackson Cates [ctb],
Evertt Sandbo [ctb]

Depends R (>= 3.5.0)

Repository CRAN

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Contents

`as.Tensor` *Converts an array to an S3 tensor*

Description

This will converts array to S3 object tensor. Vectors and matrices must first be converted to an array before applying as.Tensor.

Usage

```
as.Tensor(t)
```

Arguments

`t`	Numeric, array of numbers

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
indices <- c(2,3,4)
arr <- array(runif(prod(indices)), dim = indices)
arrT <- as.Tensor(arr); arrT
```

`fnorm` *The Frobenius Norm*

Description

The Frobenius norm of an array is the square root of the sum of its squared elements. This function works for vector and matrix arguments as well.

Usage

```
fnorm(tnsr)
```

Arguments

`tnsr`	a 3-mode tensor S3 class object

Value

The Frobenius norm

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Friedland, S., & Aliabadi, M. (2018). Linear algebra and matrices. Society for Industrial and Applied Mathematics.

Examples

```
T <- t_rand(modes=c(2,2,4))
fnorm(T$data)
```

LU *LU Decomposition of a Complex Matrix*

Description

Decomposes a a matrix into the product of a lower triangular matrix and an upper triangular matrix.

Usage

```
LU(A)
```

Arguments

A	Complex, square matrix of complex numbers

Value

A lower triangular matrix L and an upper triangular matrix U so that A=LU

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Stewart, G. W. (1998). Matrix algorithms: volume 1: basic decompositions. Society for Industrial and Applied Mathematics.

Examples

```
indices <- c(2,3,4)
z <- complex(real = rnorm(16), imag = rnorm(16))
A <- matrix(z,nrow=4)
LU(A)
```

Mnist — *Subset of MNIST training and testing data.*

Description

10000 MNIST training images (1000 of every digit), reformatted into a tensor: 28 x 10000 x 28. 1000 MNIST test images (100 of every digit), reformatted into a tensor: 28 x 1000 x 28

Usage

```
data("Mnist")
```

Format

The format is:

Mnist$train$images, Mnist$train$labels

Mnist$test$images, Mnist$test$labels

References

Deng L (2012). "The mnist database of handwritten digit images for machine learning research." IEEE Signal Processing Magazine, 29(6), 141–142

Examples

```
data("Mnist")
```

polar — *Polar/Jordan form of matrices P and D*

Description

Converts the complex matrices P and D into matrices of eigenvectors and eigenvalues with real entries.

Usage

```
polar(P,D)
```

Arguments

P	the eigenvectors from an eigenvalue decomposition.
D	the eigenvalues from an eigenvalue decomposition.

Value

P the polar form (real-valued) matrix of eigenvectors. D the polar form (real-valued) matrix of eigenvalues.

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Bhatia, R. (2013). Matrix analysis (Vol. 169). Springer Science & Business Media.

Examples

```
z <- complex(real = rnorm(16), imag = rnorm(16))
M <- matrix(z,nrow=4)
decomp <- eigen(M)
polar(decomp$vectors,decomp$values)
```

QR *QR Decomposition of a Complex Matrix without pivoting.*

Description

Decomposes a complex matrix into the product of an upper triangular matrix and a lower triangular matrix.

Usage

```
QR(A)
```

Arguments

A	square matrix with complex entries

Value

an orthogonal matrix Q and an upper triangular matrix R so that A = QR.

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Stewart, G. W. (1998). Matrix algorithms: volume 1: basic decompositions. Society for Industrial and Applied Mathematics.

Examples

```
z <- complex(real = rnorm(16), imag = rnorm(16))
A <- matrix(z,nrow=4)
QR(A)
```

---

raytrace *Subset of raytrace data*

Description

4 tensors (128 x 128 x 128) for 4 different gray scale images. boat, flashlight, keyboard, scooter.

Usage

```
data("raytrace")
```

Format

The format is:

raytrace$boat

raytrace$flashlight

raytrace$keyboard

raytrace$scooter

References

Hoover RC, Braman KS, Hao N (2011b). "Pose estimation from a single image using tensor decomposition and an algebra of circulants." In 2011 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2928–2934. IEEE.

Examples

```
data(raytrace)
```

tDWT *Discrete Wavelet Transform*

Description

Performs the Discrete Wavelet Transform of a 3-mode Tensor.

Usage

```
tDWT(tnsr)
```

Arguments

tnsr	A 3-mode Tensor

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

G. Strang and T. Nguyen, Wavelets and filter banks. SIAM, 1996. A. Haar, "Zur theorie der orthogonalen funktionensysteme", Mathematische annalen, vol. 69, no. 3, pp. 331-371, 1910.

Jensen, A., & la Cour-Harbo, A. (2011). Ripples in mathematics: the discrete wavelet transform. Springer Science & Business Media.

Examples

```
T <- t_rand(modes=c(2,3,4))
print(tDWT(T))
```

tEIG *Tensor Eigenvalue Decomposition Using any Discrete Transform*

Description

The Eigenvalue decomposition of a tensor T (n x n x k) decomposes the tensor into a tensor of eigenvectors (P) and a diagonal tensor of eigenvalues (D) so that T = P D inv(P).

Usage

```
tEIG(tnsr, tform)
```

Arguments

tnsr	a 3-mode S3 tensor class object (n x n x k)
tform	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

P, a tensor of Eigenvectors (n x n x k)

D, a diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tEIG(T,"dst")
```

`tEIGdct` *Eigenvalue decomposition of 3-mode tensor using the discrete cosine transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete cosine transform.

Usage

```
tEIGdct(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGdct(T))
```

`tEIGdht` *Eigenvalue decomposition of 3-mode tensor using the discrete Hadley transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete Hadley transform.

Usage

```
tEIGdht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGdht(T))
```

`tEIGdst` *Eigenvalue decomposition of 3-mode tensor using the discrete sine transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete sine transform.

Usage

```
tEIGdst(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGdst(T))
```

`tEIGdwht` *Eigenvalue decomposition of 3-mode tensor using the discrete Walsh Hadley transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete Walsh Hadley transform.

Usage

```
tEIGdwht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGdwht(T))
```

`tEIGdwt` *Eigenvalue decomposition of 3-mode tensor using the discrete wavelet transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete wavelet transform.

Usage

```
tEIGdwt(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGdwt(T))
```

`tEIGfft` *Eigenvalue decomposition of 3-mode tensor using the discrete fast fourier transform.*

Description

Eigenvalue decomposition of 3-mode tensor using the discrete fast fourier transform.

Usage

```
tEIGfft(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object (n x n x k)

Value

P, tensor of Eigenvectors (n x n x k)

D, diagonal tensor of Eigenvalues (n x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tEIGfft(T))
```

Tensor *Creates an S3 class for a tensor*

Description

Creates an S3 class for a tensor

Usage

```
Tensor(data, x, y, z)
```

Arguments

data	Numeric numbers in the tensor
x	mode 1 dimension
y	mode 2 dimension
z	mode 3 dimension

Value

S3 class tensor

tIDWT *Inverse Wavelet Transform*

Description

Performs inverse of 3-mode tensor using any discrete wavelet transform.

Usage

```
tIDWT(tnsr)
```

Arguments

tnsr	a 3-mode tensor S3 class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,3,4))
print(tIDWT(T))
```

---

tINV *Performs inverse of 3-mode tensor using any discrete transform.*

Description

Performs inverse of 3-mode tensor using any discrete transform.

Usage

```
tINV(tnsr, tform)
```

Arguments

tnsr	a 3-mode tensor S3 class object
tform	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tINV(T,"dst"))
```

`tINVdct` *Performs inverse of 3-mode tensor using the discrete cosine transform.*

Description

Performs inverse of 3-mode tensor using the discrete cosine transform.

Usage

```
tINVdct(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

S3 class tensor #' @examples T <- t_rand(modes=c(2,2,4)) print(tINVdct(T))

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

`tINVdht` *Performs inverse of 3-mode tensor using the discrete Hadley transform.*

Description

Performs inverse of 3-mode tensor using the discrete Hadley transform.

Usage

```
tINVdht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tINVdht(T))
```

---

tINVdst *Performs inverse of 3-mode tensor using the discrete sine transform.*

Description

Performs inverse of 3-mode tensor using the discrete sine transform.

Usage

```
tINVdst(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tINVdst(T))
```

`tINVdwht` *Performs inverse of 3-mode tensor using the discrete Walsh Hadley transform.*

Description

Performs inverse of 3-mode tensor using the discrete Walsh Hadley transform.

Usage

```
tINVdwht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tINVdwht(T))
```

`tINVdwt` *Performs inverse of 3-mode tensor using the discrete wavelet transform.*

Description

Performs inverse of 3-mode tensor using the discrete wavelet transform.

Usage

```
tINVdwt(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
tnsr <- t_rand(modes=c(2,2,4))
print(tINVdwt(tnsr))
```

---

tINVfft *Performs inverse of 3-mode tensor using the discrete fast fourier transform.*

Description

Performs inverse of 3-mode tensor using the discrete fast fourier transform.

Usage

```
tINVfft(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

Examples

```
T <- t_rand(modes=c(2,2,4))
print(tINVfft(T))
```

`tLDA` *Linear discriminate analysis (LDA) on a 3D tensor*

Description

Linear discriminate analysis (LDA) on a 3D tensor

Usage

```
tLDA(tnsr, nClass, nSamplesPerClass, tform)
```

Arguments

`tnsr`	a 3-mode tensor S3 class object
`nClass`	Number of classes
`nSamplesPerClass`	Samples in each class
`tform`	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Xanthopoulos, P., Pardalos, P. M., Trafalis, T. B., Xanthopoulos, P., Pardalos, P. M., & Trafalis, T. B. (2013). Linear discriminant analysis. Robust data mining, 27-33.

Examples

```
data("Mnist")
T <- Mnist$train$images
myorder <- order(Mnist$train$labels)
# tLDA need to be sorted by classes
T_sorted <- T$data[,myorder,]
# Using small tensor, 2 images for each class for demonstration
T <- T_sorted[,c(1:2,1001:1002,2001:2002,3001:3002,4001:4002,
5001:5002,6001:6002,7001:7002,8001:8002,9001:9002),]
tLDA(as.Tensor(T),10,2,"dct")
```

---

tLU *LU decomposition of a 3D tensor*

Description

Decomposes a 3 model tensor into a lower triangular tensor and an upper triangular tensor.

Usage

```
tLU(tnsr, tform)
```

Arguments

`tnsr`	a 3-mode tensor S3 class object
`tform`	Any discrete transform. fft: Fast Fourier Transform dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

L, The lower triangular tensor object

U, The upper triangular tensor object a Tensor3-class object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLU(T,"dst")
```

---

tLUdct *LU decomposition of a 3D tensor using the discrete cosine transform*

Description

LU decomposition of a 3D tensor using the discrete cosine transform

Usage

```
tLUdct(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUdct(T)
```

`tLUdht` *LU decomposition of a 3D tensor using the discrete Hadley transform*

Description

LU decomposition of a 3D tensor using the discrete Hadley transform

Usage

```
tLUdht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUdht(T)
```

tLUdst *LU decomposition of a 3D tensor using the discrete sine transform*

Description

LU decomposition of a 3D tensor using the discrete sine transform

Usage

```
tLUdst(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUdst(T)
```

`tLUdwht` *LU decomposition of a 3D tensor using the discrete Walsh Hadley transform*

Description

LU decomposition of a 3D tensor using the discrete Walsh Hadley transform

Usage

```
tLUdwht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUdwht(T)
```

tLUdwt *LU decomposition of a 3D tensor using the discrete wavelet transform*

Description

LU decomposition of a 3D tensor using the discrete wavelet transform

Usage

```
tLUdwt(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUdwt(T)
```

tLUfft *LU decomposition of a 3D tensor using the discrete fast fourier transform*

Description

LU decomposition of a 3D tensor using the discrete fast fourier transform

Usage

```
tLUfft(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

L, The lower triangular S3 tensor object

U, The upper triangular S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tLUfft(T)
```

`tmean` *Determines the mean of a 3D tensor along mode 2*

Description

Determines the mean of a 3D tensor along mode 2

Usage

```
tmean(tnsr)
```

Arguments

`tnsr`	a 3D tensor of dimensions n1,n2,n3

Value

S3 tensor class object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
tnsr <- t_rand(modes=c(3,4,5))
tmean(tnsr)
```

`tmult` *Tensor multiplication*

Description

Performs the tensor product of two 3D tensors using any discrete transform

Usage

```
tmult(x, y, tform)
```

Arguments

`x`	a 3-mode S3 tensor class object
`y`	a 3-mode S3 tensor class object
`tform`	Any discrete transform. fft: Fast Fourier Transform dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

S3 tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T1 <- t_rand(modes=c(2,2,4))
T2 <- t_rand(modes=c(2,3,4))
print(tmult(T1,T2,"dst"))
```

tQR *QR decomposition of a 3D tensor*

Description

Decomposes a 3 mode tensor T into the product of The left singular value tensor object and a right singular value tensor object so that T = QR.

Usage

```
tQR(tnsr, tform)
```

Arguments

tnsr	a 3-mode tensor S3 class object
tform	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

Q, The left singular value tensor object ($n \times n \times k$)

R, The right singular value tensor object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQR(T,"dst")
```

`tQRdct` *QR decomposition of a 3D tensor using the discrete cosine transform*

Description

QR decomposition of a 3D tensor using the discrete cosine transform

Usage

```
tQRdct(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRdct(T)
```

tQRdht *QR decomposition of a 3D tensor using the discrete Hadley transform*

Description

QR decomposition of a 3D tensor using the discrete Hadley transform

Usage

```
tQRdht(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRdht(T)
```

`tQRdst` *QR decomposition of a 3D tensor using the discrete sine transform*

Description

QR decomposition of a 3D tensor using the discrete sine transform

Usage

```
tQRdst(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRdst(T)
```

`tQRdwht` *QR decomposition of a 3D tensor using the discrete Walsh Hadley transform*

Description

QR decomposition of a 3D tensor using the discrete Walsh Hadley transform

Usage

```
tQRdwht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRdwht(T)
```

tQRdwt *QR decomposition of a 3D tensor using the discrete wavelet transform*

Description

QR decomposition of a 3D tensor using the discrete wavelet transform

Usage

```
tQRdwt(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRdwt(T)
```

tQRfft *QR decomposition of a 3D tensor using the fast fourier transform*

Description

QR decomposition of a 3D tensor using the fast fourier transform

Usage

```
tQRfft(tnsr)
```

Arguments

tnsr	a 3-mode S3 tensor class object

Value

Q, The left singular value S3 tensor class object ($n \times n \times k$)

R, The right singular value Se tensor class object ($n \times n \times k$)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tQRfft(T)
```

tSVD *Singular value decomposition (SVD)*

Description

Performs a Singular Value Decomposition of 3 mode tensor T using any discrete transform. The result is a left singular value tensor object U, a right singular value tensor object V, and a diagonal tensor S so that T = USV^t

Usage

```
tSVD(tnsr, tform)
```

Arguments

tnsr	a 3-mode tensor S3 class object
tform	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

If the SVD is performed on a m x n x k tensor, the components in the returned value are:

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,3,4))
print(tSVD(T,"dst"))
```

`tSVDdct` *Singular value decomposition (SVD) of a 3D tensor using the discrete cosine transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the discrete cosine transform

Usage

```
tSVDdct(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDdct(T)
```

`tSVDdht` *Singular value decomposition (SVD) of a 3D tensor using the discrete Hadley transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the discrete Hadley transform

Usage

```
tSVDdht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDdht(T)
```

`tSVDdst` *Singular value decomposition (SVD) of a 3D tensor using the discrete sine transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the discrete sine transform

Usage

```
tSVDdst(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

Kyle Caudle

Randy Hoover

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References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDdst(T)
```

`tSVDdwht` *Singular value decomposition (SVD) of a 3D tensor using the discrete Walsh Hadley transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the discrete Walsh Hadley transform

Usage

```
tSVDdwht(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

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K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDdwht(T)
```

`tSVDdwt` *Singular value decomposition (SVD) of a 3D tensor using the discrete wavelet transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the discrete wavelet transform

Usage

```
tSVDdwt(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

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References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDdwt(T)
```

`tSVDfft` *Singular value decomposition (SVD) of a 3D tensor using the fast fourier transform*

Description

Singular value decomposition (SVD) of a 3D tensor using the fast fourier transform

Usage

```
tSVDfft(tnsr)
```

Arguments

`tnsr`	a 3-mode S3 tensor class object

Value

U, the left singular value tensor object (m x m x k)

V, The right singular value tensor object (n x n x k)

S: A diagonal tensor (m x n x k)#' @examples V: The right singular value tensor object (n x n x k) S: A diagonal tensor (m x n x k)

Author(s)

Kyle Caudle

Randy Hoover

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References

M. E. Kilmer, C. D. Martin, and L. Perrone, “A third-order generalization of the matrix svd as a product of third-order tensors,” Tufts University, Department of Computer Science, Tech. Rep. TR-2008-4, 2008

K. Braman, "Third-order tensors as linear operators on a space of matrices", Linear Algebra and its Applications, vol. 433, no. 7, pp. 1241-1253, 2010.

Examples

```
T <- t_rand(modes=c(2,2,4))
tSVDfft(T)
```

t_rand *Create a random tensor*

Description

Generate a Tensor with specified modes whose entries are iid normal(0,1).

Usage

```
t_rand(modes = c(3, 4, 5))
```

Arguments

modes	the 3 modes of the output Tensor

Value

an S3 Tensor object

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Imported from rTensor2 package version 2.0.0.

Examples

```
t_rand(c(4,4,4))
```

t_tpose *Tensor transpose*

Description

Performs the transpose of a symmetric 3-mode tensor using any discrete transform.

Usage

```
t_tpose(tnsr, tform)
```

Arguments

tnsr	a 3-mode tensor
tform	Any discrete transform. fft: Fast Fourier Transorm dwt: Discrete Wavelet Transform (Haar Wavelet) dct: Discrete Cosine transform dst: Discrete Sine transform dht: Discrete Hadley transform dwht: Discrete Walsh-Hadamard transform

Value

S3 class tensor

Author(s)

Kyle Caudle

Randy Hoover

Jackson Cates

Everett Sandbo

References

Brachat, J., Comon, P., Mourrain, B., & Tsigaridas, E. (2010). Symmetric tensor decomposition. Linear Algebra and its Applications, 433(11-12), 1851-1872.

Examples

```
T <- t_rand(modes=c(2,3,4))
print(t_tpose(T,"dct"))
```

Index