Package 'BHMSMAfMRI'

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Title Bayesian Hierarchical Multi-Subject Multiscale Analysis of
Functional MRI Data

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Depends oro.nifti, wavethresh, compiler

Suggests knitr

VignetteBuilder knitr

Description Performs Bayesian hierarchical multi-subject multiscale analysis of fMRI data as described in Sanyal & Ferreira (2012) <DOI:10.1016/j.neuroimage.2012.08.041> using wavelet based prior that borrows strength across subjects and returns posterior smoothed versions of the fMRI data and samples from the posterior distribution.

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BHMSMAfMRI-package   *Bayesian Hierarchical Multi-Subject Multiscale Analysis of Functional MRI Data*

Description

Performs BHMSMA (Sanyal & Ferreira, 2012) of fMRI data using wavelet based prior that borrows strength across subjects and returns posterior smoothed versions of the fMRI data and samples from the posterior distribution. Currently considers 2D slices only.

Details

Package:	BHMSMAfMRI
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License:	GPL (>= 2)

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

BHMSMA   *Bayesian hierarchical multi-subject multiscale analysis of functional MRI data*

Description

Performs BHMSMA (Sanyal & Ferreira, 2012) of fMRI data using wavelet based prior that borrows strength across subjects and returns posterior smoothed versions of the fMRI data

Usage

```
BHMSMA(nsubject, grid, Data, DesignMatrix, TrueCoeff=NULL, analysis,
wave.family="DaubLeAsymm", filter.number=6, bc="periodic")
```

Arguments

nsubject   Number of subjects included in the analysis.

grid   The number of voxels in one row (or, one column) of the brain slice of interest.
                Must be a power of 2. The total number of voxels is grid^2. The maximum grid
                value for this package is 512.

Data   The data in form of an array with dimension (nsubject,grid,grid,ntime), where
                ntime is the size of the time series for each voxel.

DesignMatrix   The design matrix used to generate the data.

TrueCoeff   If available, the true GLM coefficients in form of an array with dimension (nsubject,grid,grid). By default, NULL.

analysis   "MSA" or "SSA", depending on whether performing multi-subject analysis or
                single subject analysis.

wave.family   The family of wavelets to use - "DaubExPhase" or "DaubLeAsymm". Default
                is "DaubLeAsymm".

filter.number   The number of vanishing moments of the wavelet. By default 6.

bc   The boundary condition to use - "periodic" or "symmetric". Default is "periodic".

Details

The wavelet computations are performed by using R package 'wavethresh'. For details, check
wavethresh package help.

Value

A list containing the following.

GLMCoeffStandardized

An array of dimension (nsubject, grid, grid), containing for each subject the
standardized GLM coefficients obtained by fitting GLM to the time-series corresponding to the voxels.

GLMEstimatedSE

An array of dimension (nsubject, grid, grid), containing for each subject the
estimated standard errors of the GLM coefficients.

WaveletCoefficientMatrix

A matrix of dimension (nsubject, grid^2-1), containing for each subject the
wavelet coefficients of all levels stacked together (by the increasing order of
resolution level).

hyperparam   A vector containing the estimates of the six hyperparameters.

hyperparamVar   Estimated covariance matrix of the hyperparameters.

pklj.bar	A matrix of dimension (nsubject, grid^2-1), containing the piklj bar values (see Reference for details).
PostMeanWaveletCoeff	
	A matrix of size (nsubject, grid^2-1), containing for each subject the posterior mean of the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).
GLMcoeffposterior	
	An array of dimension (nsubject, grid, grid), containing for each subject the posterior means of the standardized GLM coefficients.
MSE	MSE of the posterior estimates of the GLM coefficients, if the true values of the GLM coefficients are available.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Examples

```
# Should take less than a minute to run
nsubject <- 3
grid <- 8
ntime <- 4
Data <- array(rnorm(3*8*8*4),dim=c(3,8,8,4))
DesignMatrix <- cbind(c(1,0,1,0), c(1,1,1,1))
analysis <- "multi"
BHMSMA.multi <- BHMSMA(nsubject, grid, Data, DesignMatrix, TrueCoeff=NULL, analysis)
```

---

fmridata	*A simulated fMRI data for 3 subjects*

Description

A simulated fMRI data containing true regression coefficients images for three subjects and design matrix

Usage

```
data(fmridata)
```

Format

A list containing the following.

- grid =32. The image dimension is 32 by 32.
- nsubject =3.
- TrueCoeff An array of dimension (3,32,32), containing the true regression coefficients for the 3 subjects.
- DesignMatrix A matrix with 9 columns and 2 rows. The first column is a column of ones.

Details

This dataset contains only the true coefficients. The noisy fMRI data, which are generated by adding Gaussian random noise to these true coefficients, are included in the extdata directory within the package directory. The function *read.fmridata* can be used to read those data files. The true coefficients and the noisy data both are generated using the R package neuRosim. The following specifications were used to generate the data: totaltime=18, onsets=seq(1,18,by=8), durations=1, TR=2, effectsize=1, hrf="double-gamma", regions=3, radius=c(1,1,1), form="sphere", fading=1, SNR=1.5, noise="white". The centers of the activation regions were chosen manually. For information regarding the specifications, see neuRosim help.

---

glmcoeff	*Fit GLM to the data time-series and obtain GLM coefficients along with standard error estimates*

Description

Fits General Linear Model to the time-series corresponding to each voxel in the data and returns the standardized GLM coefficients and their standard error estimates.

Usage

```
glmcoeff(nsubject, grid, Data, DesignMatrix)
```

Arguments

nsubject	Number of subjects included in the analysis.
grid	The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.
Data	The data in form of an array with dimension (nsubject,grid,grid,ntime), where ntime is the size of the time series for each voxel.
DesignMatrix	The design matrix used to generate the data.

Value

A list containing the following.

GLMCoeffStandardized

> An array of dimension (nsubject, grid, grid), containing for each subject the standardized GLM coefficients obtained by fitting GLM to the time-series corresponding to the voxels.

GLMEstimatedSE

> An array of dimension (nsubject, grid, grid), containing for each subject the estimated standard errors of the GLM coefficients.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Friston, K.J., Holmes, A.P., Worsley, K.J., Poline, J., Frith, C.D., Frackowiak, R.S.J., 1994. Statistical parametric maps in functional imaging: a general linear approach. Hum. Brain Mapp. 2 (4), 189-210.

Examples

```
nsubject <- 3
grid <- 8
Data <- array(dim=c(3,8,8,10),rnorm(3*8*8*10))
DesignMatrix <- cbind( c(rep(c(1,0),5)), rep(1,10) )
glm.fit <- glmcoeff(nsubject, grid, Data, DesignMatrix)
dim(glm.fit$GLMCoeffStandardized)
#[1] 3 8 8
```

---

hyperparamest	*Get the estimates of the hyperparameters of the BHMSME model along with the estimate of their covariance matrix.*

Description

Computes the MLEs of the hyperparameters of the BHMSME model following an empirical Bayes approach and the estimate of the covariance matrix of the hyperparameters.

Usage

```
hyperparamest(nsubject, grid, WaveletCoefficientMatrix, analysis)
```

Arguments

nsubject	Number of subjects included in the analysis.
grid	The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.
WaveletCoefficientMatrix	
	A matrix of dimension (nsubject, grid^2-1), containing for each subject the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).
analysis	"multi" or "single", depending on whether performing multi-subject analysis or single subject analysis.

Value

A list containing the following.

hyperparam	A vector containing the estimates of the six hyperparameters of the BHMSME model.
hyperparamVar	Estimated covariance matrix of the hyperparameters.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Examples

```
nsubject <- 3
grid <- 8
WaveletCoefficientMatrix <- array(dim=c(3,63),rnorm(3*63))
analysis <- "multi"
hyper.est <- hyperparamest(nsubject, grid, WaveletCoefficientMatrix, analysis)
```

---

pikljbar	*Compute the piklj bar values of the BHMSMA model using Newton Cotes algorithm*

Description

Computes the values of piklj bar of the BHMSMA model using Newton Cotes algorithm. For details, check References.

Usage

```
pikljbar(nsubject, grid, WaveletCoefficientMatrix, hyperparam, analysis)
```

Arguments

nsubject   Number of subjects included in the analysis.

grid   The number of voxels in one row (or, one column) of the brain slice of interest.
                Must be a power of 2. The total number of voxels is grid^2. The maximum grid
                value for this package is 512.

WaveletCoefficientMatrix

                A matrix of dimension (nsubject, grid^2-1), containing for each subject the
                wavelet coefficients of all levels stacked together (by the increasing order of
                resolution level).

hyperparam   A vector containing the estimates of the six hyperparameters.

analysis   "MSA" or "SSA", depending on whether performing multi-subject analysis or
                single subject analysis.

Value

A list containing the following.

pklj.bar   A matrix of dimension (nsubject, grid^2-1), containing the piklj bar values.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale
analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Examples

```
nsubject <- 3
grid <- 8
WaveletCoefficientMatrix <- matrix(nrow=3,ncol=63)
for(i in 1:3)
 WaveletCoefficientMatrix[i,] <- rnorm(63)
hyperparam <- rep(.1,6)
analysis <- "multi"
piklj.bar <- pikljbar(nsubject, grid, WaveletCoefficientMatrix, hyperparam, analysis)
dim(piklj.bar$pklj.bar)
#[1]  3 63
```

---

postglmcoeff   *Obtain the posterior mean of the GLM coefficients using the posterior mean of the wavelet coefficients.*

Description

Computes the posterior mean of the GLM coefficients using the posterior mean of the wavelet coefficients by means of inverse discrete wavelet transform.

Usage

```
postglmcoeff(nsubject, grid, GLMCoeffStandardized, PostMeanWaveletCoeff,
wave.family="DaubLeAsymm", filter.number=6, bc="periodic")
```

Arguments

nsubject	Number of subjects included in the analysis.
grid	The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.
GLMCoeffStandardized	
	An array of dimension (nsubject, grid, grid), containing for each subject the standardized GLM coefficients obtained by fitting GLM to the time-series corresponding to the voxels.
PostMeanWaveletCoeff	
	A matrix of size (nsubject, grid^2-1), containing for each subject the posterior mean of the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).
wave.family	The family of wavelets to use - "DaubExPhase" or "DaubLeAsymm". Default is "DaubLeAsymm".
filter.number	The number of vanishing moments of the wavelet. By default 6.
bc	The boundary condition to use - "periodic" or "symmetric". Default is "periodic".

Details

The wavelet reconstruction is performed by using R package 'wavethresh'. For details, check wavethresh package help.

Value

A list containing the following.

GLMcoeffposterior

         An array of dimension (nsubject, grid, grid), containing for each subject the posterior means of the standardized GLM coefficients.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

Examples

```
nsubject <- 3
grid <- 8
GLMCoeffStandardized <- array(rnorm(3*8*8),dim=c(3,8,8))
PostMeanWaveletCoeff <- array(rnorm(3*63),dim=c(3,63))
postglm.coeff <- postglmcoeff(nsubject, grid, GLMCoeffStandardized, PostMeanWaveletCoeff)
dim(postglm.coeff$GLMcoeffposterior)
#[1] 3 8 8
```

---

postgroupcoeff	*Obtain posterior group coefficients using the BHMSMA methodology.*

Description

Computes posterior group coefficients using the BHMSMA methodology.

Usage

```
postgroupcoeff( nsubject, grid, GLMCoeffStandardized, PostMeanWaveletCoeff,
wave.family="DaubLeAsymm", filter.number=6, bc="periodic" )
```

Arguments

nsubject   Number of subjects included in the analysis.

grid   The number of voxels in one row (or, one column) of the brain slice of interest.
                Must be a power of 2. The total number of voxels is grid^2. The maximum grid
                value for this package is 512.

GLMCoeffStandardized

                An array of dimension (nsubject, grid, grid), containing for each subject the
                standardized GLM coefficients obtained by fitting GLM to the time-series cor-
                responding to the voxels.

PostMeanWaveletCoeff

                A matrix of size (nsubject, grid^2-1), containing for each subject the posterior
                mean of the wavelet coefficients of all levels stacked together (by the increasing
                order of resolution level).

wave.family   The family of wavelets to use - "DaubExPhase" or "DaubLeAsymm". Default
                is "DaubLeAsymm".

filter.number   The number of vanishing moments of the wavelet. By default 6.

bc   The boundary condition to use - "periodic" or "symmetric". Default is "peri-
                odic".

Details

The wavelet computations are performed by using R package 'wavethresh'. For details, check wavethresh package help.

Value

A list containing the following.

groupcoeff   A matrix of dimension (grid, grid), containing the posterior group coefficients obtained by BHMSMA methodology.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Examples

```
nsubject <- 3
grid <- 8
GLMCoeffStandardized <- array(rnorm(3*8*8),dim=c(3,8,8))
PostMeanWaveletCoeff <- array(rnorm(3*63),dim=c(3,63))
post.groupcoeff <- postgroupcoeff( nsubject, grid, GLMCoeffStandardized, PostMeanWaveletCoeff)
dim(post.groupcoeff$groupcoeff)
#[1] 8 8
```

---

postsamples   *Generate samples from the posterior distribution of the GLM coefficients.*

Description

Generates samples from the posterior distribution of the GLM coefficients.

Usage

```
postsamples(nsample, nsubject, grid, GLMCoeffStandardized, WaveletCoefficientMatrix,
hyperparam, pklj.bar, analysis, wave.family="DaubLeAsymm", filter.number=6, bc="periodic")
```

Arguments

nsample	Number of samples to be generated.
nsubject	Number of subjects included in the analysis.
grid	The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.
GLMCoeffStandardized	
	An array of dimension (nsubject, grid, grid), containing for each subject the standardized GLM coefficients obtained by fitting GLM to the time-series corresponding to the voxels.
WaveletCoefficientMatrix	
	A matrix of dimension (nsubject, grid^2-1), containing for each subject the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).
hyperparam	A vector containing the estimates of the six hyperparameters.
pklj.bar	A matrix of dimension (nsubject, grid^2-1), containing the piklj bar values (see References for details).
analysis	"MSA" or "SSA", depending on whether performing multi-subject analysis or single subject analysis.
wave.family	The family of wavelets to use - "DaubExPhase" or "DaubLeAsymm". Default is "DaubLeAsymm".
filter.number	The number of vanishing moments of the wavelet. By default 6.
bc	The boundary condition to use - "periodic" or "symmetric". Default is "periodic".

Details

The wavelet computations are performed by using R package 'wavethresh'. For details, check wavethresh package help.

Value

A list containing the following.

samples	An array of dimension (nsubject,grid,grid,nsample), containing for each subject the posterior samples of the GLM coefficients.
postdiscovery	An array of dimension (nsubject,grid,grid), containing for each subject the posterior discovery maps of the GLM coefficients (for details see Morris et al. (2011)).

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Morris, J.S. et al. (2011). Automated analysis of quantitative image data using isomorphic functional mixed models, with application to proteomic data. Ann. Appl. Stat. 5, 894-923.

Examples

```
nsubject <- 3
grid <- 8
nsample <- 5
GLMCoeffStandardized <- array(rnorm(3*8*8),dim=c(3,8,8))
WaveletCoefficientMatrix <- array(rnorm(3*63),dim=c(3,63))
hyperparam <- rep(.2,6)
pklj.bar <- array(runif(3*63),dim=c(3,63))
analysis <- "multi"
post.samples <- postsamples(nsample, nsubject, grid, GLMCoeffStandardized,
WaveletCoefficientMatrix, hyperparam, pklj.bar, analysis)
dim(post.samples$samples)
#[1] 3 8 8 5
```

---

postwaveletcoeff	*Obtain posterior mean and posterior median of the wavelet coefficients using BHMSMA methodology.*

Description

Computes posterior mean and posterior median of the wavelet coefficients using BHMSMA methodology.

Usage

```
postwaveletcoeff(nsubject, grid, WaveletCoefficientMatrix, hyperparam,
pklj.bar, analysis)
```

Arguments

nsubject   Number of subjects included in the analysis.

grid   The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.

WaveletCoefficientMatrix

                A matrix of dimension (nsubject, grid^2-1), containing for each subject the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).

hyperparam   A vector containing the estimates of the six hyperparameters.

pklj.bar	A matrix of dimension (nsubject, grid^2-1), containing the piklj bar values (see Reference for details).
analysis	"MSA" or "SSA", depending on whether performing multi-subject analysis or single subject analysis.

Value

A list containing the following.

PostMeanWaveletCoeff

A matrix of size (nsubject, grid^2-1), containing for each subject the posterior mean of the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).

PostMedianWaveletCoeff

A matrix of size (nsubject, grid^2-1), containing for each subject the posterior median of the wavelet coefficients of all levels stacked together.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

References

Sanyal, Nilotpal, and Ferreira, Marco A.R. (2012). Bayesian hierarchical multi-subject multiscale analysis of functional MRI data. Neuroimage, 63, 3, 1519-1531.

Examples

```
nsubject <- 3
grid <- 8
nsample <- 5
GLMCoeffStandardized <- array(rnorm(3*8*8),dim=c(3,8,8))
WaveletCoefficientMatrix <- array(rnorm(3*63),dim=c(3,63))
hyperparam <- rep(.2,6)
pklj.bar <- array(runif(3*63),dim=c(3,63))
analysis <- "multi"
post.waveletcoeff <- postwaveletcoeff(nsubject, grid, WaveletCoefficientMatrix,
hyperparam, pklj.bar, analysis)
dim(post.waveletcoeff$PostMeanWaveletCoeff)
#[1]  3 63
```

---

read.fmridata   *Read fMRI data from fMRI image files.*

Description

Reads fMRI data from fMRI image files into a 4D array.

Usage

```
read.fmridata( directory, format, prefix, nimages, dim.image, nii=TRUE )
```

Arguments

directory	Location of the directory where the fMRI image files are stored. Insert within quotations ("").
format	The format of the data file. One of "Analyze" (.img/.hdr files), "Nifti" (.img/.hdr files or .nii files) or "Afni" (.HEAD/.BRIK files).
prefix	If format is "Analyze" or "Nifti", then the part of the fMRI image file name appearing before the image number. The image number is assumed to have four digit representation, that is, the lowest number is 0001 and the highest possible number is 9999. If format is "Afni", then the file name. Insert within quotations("").
nimages	If format is "Analyze", number of images to be read beginning from the first image. If format is "Afni", not necessary.
dim.image	Size of the 3D fMRI image. A vector with three elements.
nii	Necessary only for "Nifti" format. nii=TRUE (default) indicates the image files are in .nii files . nii=FALSE indicates the image files are .img/.hdr files.

Details

The function uses package 'oro.nifti' for reading from fMRI data files. For details, check oro.nifti package help.

Value

A list containing the following:

fmridata	An array of dimension (dim.image, nimages), containing the image data for all images/time-points.

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

See Also

[readANALYZE](), [readNIfTI](), [readAFNI]()

Examples

```
# See package vignette.
```

---

waveletcoeff	*Apply discrete wavelet transform to the GLM coefficients and obtain the wavelet coefficients.*

Description

Applies 2D discrete wavelet transform to the standardized GLM coefficient maps and returns the wavelet coefficients of all resolution levels.

Usage

```
waveletcoeff(nsubject, grid, GLMCoeffStandardized,
wave.family="DaubLeAsymm", filter.number=6, bc="periodic")
```

Arguments

nsubject	Number of subjects included in the analysis.
grid	The number of voxels in one row (or, one column) of the brain slice of interest. Must be a power of 2. The total number of voxels is grid^2. The maximum grid value for this package is 512.
GLMCoeffStandardized	
	An array of dimension (nsubject, grid, grid), containing for each subject the standardized GLM coefficients obtained by fitting GLM to the time-series corresponding to the voxels.
wave.family	The family of wavelets to use - "DaubExPhase" or "DaubLeAsymm". Default is "DaubLeAsymm".
filter.number	The number of vanishing moments of the wavelet. By default 6.
bc	The boundary condition to use - "periodic" or "symmetric". Default is "periodic".

Details

The wavelet decomposition is performed by using R package 'wavethresh'. For details, check wavethresh package help.

Value

A list containing the following.

WaveletCoefficientMatrix

A matrix of dimension (nsubject, grid^2-1), containing for each subject the wavelet coefficients of all levels stacked together (by the increasing order of resolution level).

Author(s)

Nilotpal Sanyal <nsanyal@stanford.edu>, Marco Ferreira <marf@vt.edu>

Examples

```
nsubject <- 3
grid <- 8
Data <- array(dim=c(3,8,8,10),rnorm(3*8*8*10))
DesignMatrix <- cbind( c(rep(c(1,0),5)), rep(1,10) )
glm.fit <- glmcoeff(nsubject, grid, Data, DesignMatrix)
GLMCoeffStandardized <- glm.fit$GLMCoeffStandardized
wavelet.coeff <- waveletcoeff(nsubject, grid, GLMCoeffStandardized)
dim(wavelet.coeff$WaveletCoefficientMatrix)
#[1]  3 63
```

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