Package ‘wavethresh’

November 16, 2022

Type Package
Title Wavelets Statistics and Transforms
Version 4.7.2
Date 2022-11-14
Depends R (>= 2.10), MASS
Description Performs 1, 2 and 3D real and complex-valued wavelet transforms, nondecimated transforms, wavelet packet transforms, nondecimated wavelet packet transforms, multiple wavelet transforms, complex-valued wavelet transforms, wavelet shrinkage for various kinds of data, locally stationary wavelet time series, nonstationary multiscale transfer function modeling, density estimation.
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Description

Performs 1, 2 and 3D real and complex-valued wavelet transforms, nondecimated transforms, wavelet packet transforms, nondecimated wavelet packet transforms, multiple wavelet transforms, complex-valued wavelet transforms, wavelet shrinkage for various kinds of data, locally stationary wavelet time series, nonstationary multiscale transfer function modeling, density estimation.

Details

Package: wavethresh
Type: Package
Title: Wavelets Statistics and Transforms
Version: 4.7.2
Date: 2022-11-14
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Depends: R (>= 2.10), MASS
Description: Performs 1, 2 and 3D real and complex-valued wavelet transforms, nondecimated transforms, wavelet packet transforms, nondecimated wavelet packet transforms, multiple wavelet transforms, complex-valued wavelet transforms, wavelet shrinkage for various kinds of data, locally stationary wavelet time series, nonstationary multiscale transfer function modeling, density estimation.
License: GPL (>=2)
Author: Guy Nason [aut, cre], Stuart Barber [ctb], Tim Downie [ctb], Piotr Frylewicz [ctb], Arne Kovac [ctb], Todd Ogden [ctb], Bernard Silverman [ctb]
Maintainer: Guy Nason <g.nason@imperial.ac.uk>
Index of help topics:

**AutoBasis** Run Coifman-Wickerhauser best basis algorithm on wavelet packet object

**AvBasis** Basis averaging ("inversion")

**AvBasis.wst** Perform basis averaging for (packet-ordered) non-decimated wavelet transform.

**AvBasis.wst2D** Perform basis averaging for (packet-ordered) 2D non-decimated wavelet transform.

**BAYES.THR** Bayesian wavelet thresholding.

**BMdiscr** Subsidiary routine for makewpsID0 function

**BabyECG** Physiological data time series.

**BabySS** Physiological data time series.

**Best1DCols** Extract the best (one-dimensional) nondecimated WP packets

**CWave** C Wavelet Cross-validation

**CWaveDE** Simple wavelet density estimator with hard thresholding

**CanUseMoreThanOneColor** Deprecated function

**Chires5** Subsid routine for denproj (calcs scaling function coffs without cov)

**Chires6** Subsid routine for denproj (calcs scaling function coffs with cov)

**ConvertMessage** Print out a text message about an object which is from old version of WaveThresh

**Crsswav** Wrapper to C code version of rsswav

**Cthreshold** Calls C code to threshold wd class object.

**DJ.EX** Produce Donoho and Johnstone test functions

**FullWaveletCV** Perform whole wavelet cross-validation in C code

**GenW** Generate (inverse) discrete wavelet transform matrix.

**GetRSSWST** Computes estimate of error for function estimate.

**HaarConcat** Generate a concatenated Haar MA process

**HaarMA** Generate Haar MA processes.

**InvBasis** Generic basis inversion for libraries

**InvBasis.wp** Invert a wp library representation with a particular basis spec

**InvBasis.wst** Invert a wst library representation with a basis specification

**IsEarly** Generic function to detect whether object is from an early version

**IsEarly.default** Detects whether object is from an earlier version of WaveThresh

**IsEarly.wd** Function to detect whether a wd object is from WaveThresh2 or not

**IsPowerOfTwo** Decides whether vector elements are integral
powers of two (returns NA if not).

**LSWsim**  
Simulate arbitrary locally stationary wavelet process.

**LocalSpec**  
Compute Nason and Silverman smoothed wavelet periodogram.

**LocalSpec.wd**  
Compute Nason and Silverman raw or smoothed wavelet periodogram.

**LocalSpec.wst**  
Obsolete function (use ewspecl)

**MaNoVe**  
Make Node Vector (using Coifman-Wickerhauser best-basis type algorithm)

**MaNoVe.wp**  
Make Node Vector (using Coifman-Wickerhauser best-basis type algorithm) on wavelet packet object

**MaNoVe.wst**  
Make Node Vector (using Coifman-Wickerhauser best-basis type algorithm) on nondecimated wavelet transform object

**PsiJ**  
Compute discrete autocorrelation wavelets.

**PsiJmat**  
Compute discrete autocorrelation wavelets but return result in matrix form.

**Psiname**  
Return a PsiJ list object style name.

**ScalingFunction**  
Compute scaling functions on internally predefined grid

**Shannon.entropy**  
Compute Shannon entropy

**TOgetthrdal**  
Subsidiary routines for Ogden and Parzen's wavelet shrinkage methods

**TOthreshda1**  
Data analytic wavelet thresholding routine

**TOthreshda2**  
Data analytic wavelet thresholding routine

**WTEnv**  
Environment that exists to store intermediate calculations for re-use within the same R session.

**WaveletCV**  
Wavelet cross-validation

**Whistory**  
Obsolete function supposedly detailed history of object

**Whistory.wst**  
Obsolete function: as Whistory, but for wst objects

**accessC**  
Get "detail" (mother wavelet) coefficients data from wavelet object

**accessC.mwd**  
Get Smoothed Data from Wavelet Structure

**accessC.wd**  
Get smoothed data from wavelet object (wd)

**accessC.wp**  
Warning function when trying to access smooths from wavelet packet object (wp).

**accessC.wst**  
Get smoothed data from packet ordered non-decimated wavelet object (wst)

**accessD**  
Get "detail" (mother wavelet) coefficients data from wavelet object

**accessD.mwd**  
Get wavelet coefficients from multiple wavelet structure (mwd).

**accessD.wd**  
Get detail (mother wavelet) coefficients from
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denproj Calculate empirical scaling function coefficients of a p.d.f.
denwd Wavelet decomposition of empirical scaling function coefficients of a p.d.f.
denwr Wavelet reconstruction for density estimation.
dof Compute number of non-zero coefficients in wd object
doppler Evaluate the Donoho and Johnstone Doppler signal.
draw Draw wavelets or scaling functions.
draw.default Draw picture of a wavelet or scaling function.
draw.imwd Draw mother wavelet associated with an imwd object.
draw.imwdc Draw mother wavelet associated with an imwdc object.
draw.mwd Draws a wavelet or scaling function used to compute an 'mwd' object
draw.wd Draw mother wavelet or scaling function associated with wd object.
draw.wp Draw wavelet packet associated with a wp object.
draw.wst Draw mother wavelet or scaling function associated with wst object.
drawbox Draw a shaded coloured box
drawwp.default Subsidiary routine that actually computes wavelet packet values
ewspec Compute evolutionary wavelet spectrum estimate.
example.1 Compute and return piecewise polynomial coordinates.
filter.select Provide wavelet filter coefficients.
find.parameters Find estimates of prior parameters
first.last Build a first/last database for wavelet transforms.
first.last.dh Build special first/last database for some wavelet density functions
firstdot Return the location of the first period character within a character string (for a vector of strings of arbitrary length).
getarrvec Compute and return weaving permutation for conversion from wst objects to wd class objects.
getpacket Get a packet of coefficients from a wavelet object
getpacket.wp Get packet of coefficients from a wavelet packet object (wp).
getpacket.wpst Get packet of coefficients from a non-decimated wavelet packet object (wpst).
getpacket.wst Get packet of coefficients from a packet
ordered non-decimated wavelet object (wst).

getpacket.wst2D Get packet of coefficients from a two-dimensional non-decimated wavelet object (wst2D).

griddata objects Data interpolated to a grid objects.
guyrot Cyclically rotate elements of a vector
image.wd Produce image representation of nondecimated wavelet transform
image.wst Produce image representation of a wst class object
imwd Two-dimensional wavelet transform (decomposition).
imwd.object Two-dimensional wavelet decomposition objects.
imwdc.object Two-dimensional compressed wavelet decomposition objects.
imwr Inverse two-dimensional wavelet transform.
imwr.imwd Inverse two-dimensional discrete wavelet transform.
imwr.imwdc Inverse two-dimensional discrete wavelet transform.

ipd Inductance plethysmography data.
ipndacw Compute inner product matrix of discrete non-decimated autocorrelation wavelets.
irregwd Irregular wavelet transform (decomposition).
irregwd.objects Irregular wavelet decomposition objects.
l2norm Compute L2 distance between two vectors of numbers.
lennon John Lennon image.
levarr Subsidiary routine that generates a particular permutation
linfnorm Compute L infinity distance between two vectors of numbers.
logabs Take the logarithm of the squares of the argument
lt.to.name Convert desired level and orientation into code used by imwd
madmad Compute square of median absolute deviation (mad) function.
make.dwwt Compute diagonal of the matrix WWT
makegrid Interpolate data to a grid.
makewpstDO Help page for a function
makewpstRO Make a wavelet packet regression object from a dependent and independent time series variable.
mfilter.select Provide filter coefficients for multiple wavelets.
mfirst.last Build a first/last database for multiple wavelet transforms.
modernise Generic function to upgrade a V2 WaveThresh
modernise.wd Modernise a wd class object
mpostfilter Multiwavelet postfilter
mprefilter Multiwavelet prefilter
mwd Discrete multiple wavelet transform (decomposition).
mwd.object Multiple wavelet decomposition object (1D)
mwr Multiple discrete wavelet transform (reconstruction).
newsure Version of sure that acts as subsidiary for
threshold.irregwd
nlevelsWT Returns number of scale (resolution) levels.
nlevelsWT.default Returns number of levels associated with an
object
nullevels Set whole resolution levels of coefficients
equal to zero.
nullevels.imwd Sets whole resolution levels of coefficients
equal to zero in a imwd object.
nullevels.wd Sets whole resolution levels of coefficients
equal to zero in a wd object.
nullevels.wst Sets whole resolution levels of coefficients
equal to zero in a wst object.
nvlontonv Convert an index number into a node vector
object.
nv.object Node vector objects.
plot.imwd Draw a picture of the 2D wavelet coefficients
using image
plot.irregwd Plot variance factors of wavelet transform coefficients for irregularly spaced wavelet
transform object
plot.mwd Use plot on an mwd object.
plot.nvwp Depict wavelet packet basis specification
plot.wd Plot wavelet transform coefficients.
plot.wp Plot wavelet packet transform coefficients
plot.wst Plot packet-ordered non-decimated wavelet
transform coefficients.
plot.wst2D Plot packet-ordered 2D non-decimated wavelet
coefficients.
plotdenwd Plot the wavelet coefficients of a p.d.f.
plotpkt Sets up a high level plot ready to show the
time-frequency plane and wavelet packet basis
slots
print.BP Print top best basis information for BP class
object
print.imwd Print out information about an imwd object in
readable form.
print.imwdc Print out information about an imwdc object in
readable form.
print.mwd Use print() on a mwd object.
print.nv Print a node vector object, also used by several other functions to obtain packet list information
print.nvwp Print a wavelet packet node vector object, also used by several other functions to obtain packet list information
print.w2d Print method for printing w2d class objects
print.w2m Print a w2m class object
print.wd Print out information about an wd object in readable form.
print.wd3D Print out information about an wd3D object in a readable form.
print.wp Print out information about an wd object in readable form.
print.wpst Prints out basic information about a wpst class object
print.wpstCL Prints some information about a wpstCL object
print.wpstDO Print information about a wpstDO class object
print.wpstRO Print a wpstRO class object
print.wst Print out information about an wst object in readable form.
print.wst2D Print out information about an wst2d object in a readable form.

putC Put smoothed data (father wavelet) coefficients into wavelet structure
putC.mwd Put smoothed data into wavelet structure
putC.wd Puts a whole resolution level of father wavelet coefficients into wd wavelet object.
putC.wp Warning function when trying to insert father wavelet coefficients into wavelet packet object (wp).
putC.wst Puts a whole resolution level of father wavelet coefficients into wst wavelet object.

putD Put mother wavelet coefficients into wavelet structure
putD.mwd Put wavelet coefficients into multiple wavelet structure
putD.wd Puts a whole resolution level of mother wavelet coefficients into wd wavelet object.
putD.wd3D Put wavelet coefficient array into a 3D wavelet object
putD.wp Puts a whole resolution level of wavelet packet coefficients into wp wavelet object.
putD.wst Puts a whole resolution level of mother wavelet coefficients into wst wavelet object.

putDwd3Dcheck Check argument list for putD.wd3D
putpacket Insert a packet of coefficients into a wavelet structure.
putpacket.wp
Inserts a packet of coefficients into a wavelet packet object (wp).

putpacket.wst
Put a packet of coefficients into a packet ordered non-decimated wavelet object (wst).

putpacket.wst2D
Replace packet of coefficients in a two-dimensional non-decimated wavelet object (wst2D).

rcov
Computes robust estimate of covariance matrix

rfft
Real Fast Fourier transform

rfftinv
Inverse real FFT, inverse of rfft

rfftwt
Weight a Fourier series sequence by a set of weights

rm.det
Set coarse levels of a wavelets on the interval transform object to zero

rmget
Search for existing ipndacw matrices.

rmname
Return a ipndacw matrix style name.

rotateback
Cyclically shift a vector one place to the right

rsswav
Compute mean residual sum of squares for odd prediction of even ordinates and vice versa

simchirp
Compute and return simulated chirp function.

ssq
Compute sum of squares difference between two vectors

summary.imwd
Print out some basic information associated with an imwd object

summary.imwdc
Print out some basic information associated with an imwdc object

summary.mwd
Use summary() on a mwd object.

summary.wd
Print out some basic information associated with a wd object

summary.wd3D
Print out some basic information associated with a wd3D object

summary.wp
Print out some basic information associated with a wp object

summary WPST
Print out some basic information associated with a wpst object

summary.wst
Print out some basic information associated with a wst object

summary.wst2D
Print out some basic information associated with a wst2D object

support
Returns support of compactly supported wavelets.

sure
Computes the minimum of the SURE thresholding function

teddy
Picture of a teddy bear's picnic.

test.dataCT
Test functions for wavelet regression and thresholding
threshold

threshold.imwd

Threshold two-dimensional wavelet decomposition object

threshold.imwdc

Threshold two-dimensional compressed wavelet decomposition object

threshold.irregwd

hold irregularly spaced wavelet decomposition object

threshold.mwd

Use threshold on an mwd object.

threshold.wd

Threshold (DWT) wavelet decomposition object

threshold.wd3D

Threshold 3D DWT object

threshold.wp

Threshold wavelet packet decomposition object

threshold.wst

Threshold (NDWT) packet-ordered non-decimated wavelet decomposition object

tpwd

Tensor product 2D wavelet transform

tpwr

Inverse tensor product 2D wavelet transform.

uncompress

Uncompress objects

uncompress.default

Undo zero run-length encoding for a vector.

uncompress.imwdc

Uncompress an imwdc class object

wavegrow

Interactive graphical tool to grow a wavelet synthesis

wavethresh-package

Wavelets Statistics and Transforms

wd

Wavelet transform (decomposition).

wd.dh

Compute specialized wavelet transform for density estimation

wd.int

Computes "wavelets on the interval" transform

wd.object

Wavelet decomposition objects

wd3D

Three-dimensional discrete wavelet transform

wd3D.object

Three-dimensional wavelet object

wp

Wavelet packet transform.

wp.object

Wavelet Packet decomposition objects.

wpst

Non-decimated wavelet packet transform.

wpst2discr

Reshape/reformat packet coefficients into a multivariate data set

wpst2m

Converts a nondecimated wavelet packet object to a (large) matrix with packets stored as columns

wpstCLASS

Predict values using new time series values via a non-decimated wavelet packet discrimination object.

wpstREGR

Construct data frame using new time series using information from a previously constructed wpstRO object

wr

Wavelet reconstruction (inverse DWT).

wr.int

Computes inverse "wavelets on the interval" transform.

wr.mwd

Multiple wavelet reconstruction for mwd objects

wr.wd

Wavelet reconstruction for wd class objects (inverse discrete wavelet transform).
wavethresh-package

wr3D
- Inverse DWT for 3D DWT object.

wst
- Packet-ordered non-decimated wavelet transform.

wst.object
- (Packet ordered) Nondecimated wavelet transform decomposition objects.

wst2D
- (Packet-ordered) 2D non-decimated wavelet transform.

wst2D.object
- (Packet ordered) Two-dimensional nondecimated wavelet transform decomposition objects.

wstCV
- Performs two-fold cross-validation estimation using packet-ordered non-decimated wavelet transforms and one, global, threshold.

wstCVl
- Performs two-fold cross-validation estimation using packet-ordered non-decimated wavelet transforms and a (vector) level-dependent threshold.

wvcvlrss
- Computes estimate of error for function estimate.

wvmoments
- Compute moments of wavelets or scaling function

wvrelease
- Prints out the release number of the WaveThresh package

See book or individual help pages for main functions. For example, \texttt{wd} for the one-dimensional discrete wavelet transform.

Author(s)

NA

Maintainer: NA

References


See Also

\texttt{ews}, \texttt{imw}, \texttt{threshold}, \texttt{wd}, \texttt{wst}

Examples

#
# See examples in individual help pages
#
accessC

Get "detail" (mother wavelet) coefficients data from wavelet object

Description

This generic function extracts detail from various types of wavelet objects. It extracts and returns a whole resolution level of coefficients. To obtain individual packets from relevant transforms use the getpacket() series of functions. This function is generic.

Particular methods exist. For objects of class:

- **wd** use the `accessC.wd` method
- **wp** use the `accessC.wp` method
- **wst** use the `accessC.wst` method

See individual method help pages for operation and examples.

Usage

`accessC(...)`

Arguments

... 

See individual help for details.

Value

A vector coefficients representing the detail coefficients for the requested resolution level.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

`accessC.wd, accessC.wp, accessC.wst, accessD`
accessc

Get variance information from irregularly spaced wavelet decomposition object.

Description

This function gets information from the c component of an `irregwd.objects` an irregularly spaced wavelet decomposition object.

Note that this function is not the same as `accessC` which obtains father wavelet coefficients from an `wd` class object.

Usage

```r
accessc(irregwd.structure, level, boundary=FALSE)
```

Arguments

- `irregwd.structure`: Irregular wavelet decomposition object from which you wish to extract parts of the c component from.
- `level`: The level that you wish to extract. This value ranges from 0 to the `nlevelsWT(irregwd.structure)` - 1.
- `boundary`: If this argument is T then all of the boundary correction values will be returned as well (note: the length of the returned vector may not be a power of 2). If boundary is false, then just the coefficients will be returned. If the decomposition (or reconstruction) was done with periodic boundary conditions then this option has no effect.

Details

The `irregwd` function produces a irregular wavelet decomposition (reconstruction) structure.

The c component is stored in a similar way to the C and D vectors which store the father and mother wavelet coefficients respectively. Hence to access the information the accessc function plays a similar role to `accessC` and `accessD` functions.

Value

A vector of the extracted data.

RELEASE


Author(s)

G P Nason
accessC.mwd

See Also

irregwd, irregwd.objects, threshold.irregwd, makegrid, plot.irregwd

Examples

# Most users will not need to use this function. However, see the main
# examples for the irregular wavelet denoising in the examples for
# makegrid.
#

accessC.mwd

Get Smoothed Data from Wavelet Structure

Description

The smoothed and original data from a multiple wavelet decomposition structure, mwd.object ect
e.g. returned from mwd) are packed into a single matrix in that structure. TRUE his function extracts
the data corresponding to a particular resolution level.

Usage

## S3 method for class 'mwd'
accessC(mwd, level = nlevelsWT(mwd), ...)

Arguments

mwd Multiple wavelet decomposition structure from which you wish to extract the
smoothed or original data if the structure is from a wavelet decomposition, or
the reconstructed data if the structure is from a wavelet reconstruction.

level The level that you wish to extract. By default, this is the level with most detail
(in the case of structures from a decomposition this is the original data, in the
case of structures from a reconstruction this is the top-level reconstruction).

... any other arguments

Details

The mwd function produces a wavelet decomposition structure.
For decomposition, the top level contains the original data, and subsequent lower levels contain the
successively smoothed data. So if there are mwd$filter$npal$2^m original data points (mwd$filter$npal
is the multiplicity of wavelets), there will be $m+1$ levels indexed 0,1,...,m. So
accessC.mwd(Mwd, level=m)
pulls out the original data, as does
accessC.mwd(mwd)
To get hold of lower levels just specify the level that you're interested in, e.g.
accessC.mwd(mwd, level=2)

Gets hold of the second level.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear matrix of coefficients. AccessC obtains information about where the smoothed data appears from the fl.dbase component of mwd, in particular the array fl.dbase$first.last.c which gives a complete specification of index numbers and offsets for mwd$C.

Note also that this function only gets information from mwd class objects. To put coefficients into mwd structures you have to use the putC.mwd function.


Value

A matrix with mwd$filter$npsi rows containing the extracted data of all the coefficients at that level.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6.)

Author(s)

G P Nason

See Also

accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd

Examples

#
# Get the 3rd level of smoothed data from a decomposition
#
dat <- rnorm(32)
accessC.mwd(mwd(dat), level=3)
Usage

## S3 method for class 'wd'
accessC(wd, level = nlevelsWT(wd), boundary=FALSE, aspect, ...)

Arguments

- **wd** wavelet decomposition structure from which you wish to extract the smoothed or original data if the structure is from a wavelet decomposition, or the reconstructed data if the structure is from a wavelet reconstruction.
- **level** the level that you wish to extract. By default, this is the level with most detail (in the case of structures from a decomposition this is the original data, in the case of structures from a reconstruction this is the top-level reconstruction).
- **boundary** logical; if TRUE then all of the boundary correction values will be returned as well (note: the length of the returned vector may not be a power of 2). If boundary is false, then just the coefficients will be returned. If the decomposition (or reconstruction) was done with periodic boundary conditions, this option has no effect.
- **aspect** Applies a function to the coefficients before return. Supplied as a text string which gets converted to a function. For example, "Mod" for complex-valued arguments
- ... any other arguments

Details

The **wd (wr.wd)** function produces a wavelet decomposition (reconstruction) structure.

For decomposition, the top level contains the original data, and subsequent lower levels contain the successively smoothed data. So if there are $2^m$ original data points, there will be $m+1$ levels indexed 0,1,\ldots,m. So

```r
accessC.wd(wdobj, level=m)
```

pulls out the original data, as does

```r
accessC.wd(wdobj)
```

To get hold of lower levels just specify the level that you’re interested in, e.g.

```r
accessC.wd(wdobj, level=2)
```

gets hold of the second level.

For reconstruction, the top level contains the ultimate step in the Mallat pyramid reconstruction algorithm, lower levels are intermediate steps.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear vector. AccessC obtains information about where the smoothed data appears from the fl.dbase component of an **wd.object**, in particular the array fl.dbase$first.last.c which gives a complete specification of index numbers and offsets for **wd.object$C**.

Note that this function is method for the generic function **accessC**. When the **wd.object** is definitely a wd class object then you only need use the generic version of this function.
Note that this function only gets information from `wd` class objects. To insert coefficients etc. into `wd` structures you have to use the `putC` function (or more precisely, the `putC.wd` method).

**Value**

A vector of the extracted data.

**Description**

There are no real smooths to access in a `wp` wavelet packet object. This function returns an error message. To obtain coefficients from a wavelet packet object you should use the `getpacket` collection of functions.

**Usage**

```r
## S3 method for class 'wp'
accessC(wp, ...)```

---

**Examples**

```r
## Get the 3rd level of smoothed data from a decomposition
dat <- rnorm(64)
accessC(wd(dat), level=3)
```
**Arguments**

- **wp**: Wavelet packet object.
- **...**: any other arguments

**Value**

An error message!

**RELEASE**

Version 3.5.3 Copyright Guy Nason 1994

**Author(s)**

G P Nason

**See Also**

getpacket

---

**accessC.wst**

*Get smoothed data from packet ordered non-decimated wavelet object (wst)*

**Description**

The smoothed data from a packet ordered non-decimated wavelet object (returned from `wst`) are stored in a matrix. This function extracts all the coefficients corresponding to a particular resolution level.

**Usage**

```r
## S3 method for class 'wst'
accessC(wst, level, aspect, ...)
```

**Arguments**

- **wst**: Packet ordered non-decimated wavelet object from which you wish to extract the smoothed or original data (if the object is directly from a packet ordered non-decimated wavelet transform of some data).
- **level**: The level that you wish to extract. This can range from zero (the coarsest coefficients) to `nlevelsWT(wstobj)` which returns the original data.
- **aspect**: Applies function to coefficients before return. Supplied as a character string which gets converted to a function. For example "Mod" which returns the absolute values of the coefficients.
- **...**: Other arguments
Details

The `wst` function performs a packet-ordered non-decimated wavelet transform. This function extracts all the father wavelet coefficients at a particular resolution level specified by `level`.

Note that coefficients returned by this function are in emphpacket order. They can be used as is but for many applications it might be more useful to deal with the coefficients in packets: see the function `getpacket.wst` for further details.

Value

A vector of the extracted data.

Author(s)

G P Nason

References


See Also

`wst`, `wst.object`, `accessC`, `getpacket.wst`

Examples

```r
# Get the 3rd level of smoothed data from a decomposition
#
# dat <- rnorm(64)
accessC(wst(dat), level=3)
```

Description

This generic function extracts detail from various types of wavelet objects. It extracts and returns a whole resolution level of coefficients. To obtain individual packets from relevant transforms use the `getpacket()` series of functions. This function is generic.

Particular methods exist. For objects of class:

- `wd` use the `accessD.wd` method
- `wd3D` use the `accessD.wd3D` method
- `wp` use the `accessD.wp` method
- `wpst` use the `accessD.wpst` method
- `wst` use the `accessD.wst` method

See individual method help pages for operation and examples.
accessD.mwd

Usage
accessD(...)

Arguments
... See individual help for details.

Value
A vector coefficients representing the detail coefficients for the requested resolution level.

RELEASE
Version 3.5.3 Copyright Guy Nason 1994

Author(s)
G P Nason

See Also
accessD.wd, accessD.wp, accessD.wst, accessC

Access coefficients from multiple wavelet structure (mwd).

Description
The wavelet coefficients from a multiple wavelet decomposition structure, mwd.object, (e.g. returned from mwd) are packed into a single matrix in that structure. This function extracts the coefficients corresponding to a particular resolution level.

Usage
### S3 method for class 'mwd'
accessD(mwd, level, ...)

Arguments
mwd Multiple wavelet decomposition structure from which you wish to extract the expansion coefficients.
level The level that you wish to extract. If the "original" data has mwd$filter$npsi \times 2^m data points (mwd$filter$npsi being the multiplicity of the multiple wavelets) then there are m possible levels that you could want to access, indexed by 0,1,...,(m-1)
... any other arguments
The `mwd` function produces a multiple wavelet decomposition object.

The need for this function is a consequence of the pyramidal structure of Mallat's algorithm and the memory efficiency gain achieved by storing the pyramid as a linear matrix. AccessD obtains information about where the coefficients appear from the fl.dbase component of `mwd`, in particular the array `fl.dbase$first.last.d` which gives a complete specification of index numbers and offsets for `mwd$D`.

Note that this function and `accessC` only work on objects of class `mwd` to extract coefficients. You have to use `putD.mwd` to insert wavelet coefficients into a `mwd` object.


**Value**

A matrix with `mwd$filter$np` rows containing the extracted coefficients.

**Examples**

```r
# Get the 3rd level of smoothed data from a decomposition
#
data(ipd)
accessD.mwd(mwd(ipd), level=3)
```

---

**accessD.wd**

*Get detail (mother wavelet) coefficients from wavelet object (wd).*

**Description**

This function extracts and returns a vector of mother wavelet coefficients, corresponding to a particular resolution level, from a `wd` wavelet decomposition object.

The pyramid of coefficients in a wavelet decomposition (returned from the `wd` function, say) are packed into a single vector in WaveThresh.
Usage

## S3 method for class 'wd'
accessD(wd, level, boundary=FALSE, aspect="Identity", ...)

Arguments

wd
Wavelet decomposition object from which you wish to extract the mother wavelet coefficients.

level
The resolution level at which you wish to extract coefficients.

boundary
some methods of wavelet transform computation handle the boundaries by keeping some extra bookkeeping coefficients at either end of a resolution level. If this argument is TRUE then these bookkeeping coefficients are returned when the mother wavelets are returned. Otherwise, if FALSE, these coefficients are not returned.

aspect
The aspect argument permits the user to supply a function to modify the returned coefficients. The function is applied to the vector of coefficients before it is returned. This can be useful, say, with the complex DWT where you could supply aspect="Mod" if you wanted to return the modulus of the coefficients at a given resolution level. The default argument, "Identity", ensures that the coefficients are not modified before returning.

... any other arguments

Details

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear vector. AccessD obtains information about where the smoothed data appears from the fl.dbase component of an wd object, in particular the array

fl.dbase$first.last.d

which gives a complete specification of index numbers and offsets for

wd.object$D.

Note that this function is a method for the generic function accessD.

Note also that this function only retrieves information from wd class objects. To insert coefficients into wd objects you have to use the putD function (or more precisely, the putD.wd method).

Value

A vector containing the mother wavelet coefficients at the required resolution level (the coefficients might have been modified depending on the value of the aspect argument).

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason
References


See Also

wr, wd, accessD, filter.select, threshold

Examples

```r
# Get the 4th resolution level of wavelet coefficients.
#
dat <- rnorm(128)
accessD(wd(dat), level=4)
```

---

accessD.wd3D  
*Get wavelet coefficients from 3D wavelet object*

Description

This function extracts and returns arrays of wavelet coefficients, corresponding to a particular resolution level, from a `wd` wavelet decomposition object.

The pyramid of coefficients in a wavelet decomposition (returned from the `wd3D` function, say) are packed into a single array in `WaveThresh3`.

Usage

```r
## S3 method for class 'wd3D'
accessD(obj, level = nlevelsWT(obj)-1, block, ...)
```

Arguments

- `obj`  
  3D Wavelet decomposition object from which you wish to extract the wavelet coefficients.

- `level`  
  The resolution level at which you wish to extract coefficients. The minimum level you can enter is 0, the largest is one less than the number of nlevelsWT stored in the obj object.

- `block`  
  if block is missing then a list containing all of the wavelet coefficient blocks GGG, GGH, GHG, GHH, HGG, HGH, HHG (and HHH, if level=0) is returned. Otherwise block should be one of the character strings GGG, GGH, GHG, GHH, HGG, HGH, HHG and then only that sub-block is returned from the resolution level specified.

- `...`  
  any other arguments
Details

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as an array.

Note that this function is a method for the generic function `accessD`.

Value

If the block is missing then a list is returned containing all the sub-blocks of coefficients for the specified resolution level.

Otherwise the block character string specifies which sub-block of coefficients to return.

RELEASE

Version 3.9.6 Copyright Guy Nason 1997

Author(s)

G P Nason

See Also

`link{accessD}`, `link{print.wd3D}`, `link{putD.wd3D}`, `link{putDwd3Dcheck}`, `link{summary.wd3D}`, `link{threshold.wd3D}`, `link{wd3D}`, `link{wd3D object}`, `link{wr3D}`.

Examples

```r
# Generate some test data
#
a <- array(rnorm(8*8*8), dim=c(8,8,8))
#
# Perform the 3D DWT
#
awd3D <- wd3D(a)
#
# How many levels does this object have?
#
levelsWT(awd3D)
# [1] 3
#
# So conceivably we could access levels 0, 1 or 2.
#
# Ok. Let's get the level 1 HGH sub-block coefficients:
#
accessD(awd3D, level=1, block="HGH")
#
[,1] [,2]
[1,] 0.8359289 1.3596832
[2,] -0.1771688 0.2987303
```
accessD.wp

Obtain whole resolution level of wavelet packet coefficients from a wavelet packet object (wp).

Description

Get a whole resolution level's worth of coefficients from a wp wavelet packet object. To obtain packets of coefficients from a wavelet packet object you should use the getpacket collection of functions.

Usage

```r
## S3 method for class 'wp'
accessD(wp, level, ...)
```
Arguments

wp  Wavelet packet object.
level  the resolution level that you wish to extract.
...  any other arguments

Details

The wavelet packet coefficients are actually stored in a straightforward manner in a matrix component of a \textit{wp} object so it would not be too difficult to extract whole resolution levels yourself. However, this routine makes it easier to do.

Value

A vector containing the coefficients that you wanted to extract.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

\texttt{accessD}, \texttt{getpacket}

---

\texttt{accessD.wpst} \hspace{1cm} \textit{Get coefficients from a non-decimated wavelet packet object (wpst) in time order.}

Description

The coefficients from a non-decimated wavelet packet object, \texttt{wpst}, are stored in a particular order in the \texttt{wpst} component of the \texttt{wpstobj} object. This function extracts all the coefficients corresponding to a particular wavelet packet in time order.

Usage

## S3 method for class 'wpst'
accessD(wpst, level, index, ...)

---
Arguments

wpst  Non-decimated wavelet packet object from which you wish to extract time-ordered coefficients.

level  The resolution level that you wish to extract. This can range from zero (the coarsest coefficients) to nlevelsWT-1(wstobj) which are the finest scale coefficients.

index  The wavelet packet index that you require (sequency ordering). This can range from 0 (father wavelet coefficients) to $2^{(n\text{levelsWT} - \text{level})} - 1$, i.e. the maximum is dependent on the resolution level.

...  any other arguments

Details

The `wpst` function performs a non-decimated wavelet packet transform. This function extracts the coefficients at a particular resolution level specified by level in time order.

It is possible to extract the individual packets (before interweaving, i.e. the direct result of multiple applications of the packet operators) by using the `getpacket.wpst` function.

Author(s)

G P Nason

References


See Also

`wpst`, `wpst.object`, `accessD`, `getpacket.wpst`

Examples

```r
# Get the 4th level of coefficients from a decomposition
#
# dat <- rnorm(128)
accessD(wpst(dat), level=4, index=3)
```
Get mother wavelet coefficients from a packet ordered non-decimated wavelet object (wst).

**Description**

The mother wavelet coefficients from a packet ordered non-decimated wavelet object, \texttt{wst}, are stored in a matrix. This function extracts all the coefficients corresponding to a particular resolution level.

**Usage**

```r
## S3 method for class 'wst'
accessD(wst, level, aspect = "Identity", ...)
```

**Arguments**

- \texttt{wst} Packet ordered non-decimated wavelet object from which you wish to extract the mother wavelet coefficients.
- \texttt{level} The level that you wish to extract. This can range from zero (the coarsest coefficients) to \texttt{nlevelsWT(wstobj)} which returns the original data.
- \texttt{aspect} Function to apply to coefficient before return. Supplied as a character argument which gets converted to a function. For example, "Mod" which returns the absolute value of complex-valued coefficients.
- \texttt{...} Other arguments

**Details**

The \texttt{wst} function performs a packet-ordered non-decimated wavelet transform. This function extracts all the mother wavelet coefficients at a particular resolution level specified by \texttt{level}.

Note that coefficients returned by this function are in packet order. They can be used as is but for many applications it might be more useful to deal with the coefficients in packets: see the function \texttt{getpacket.wst} for further details.

Note that all the coefficients here are those of mother wavelets. The non-decimated transform efficiently computes all possible shifts of the discrete wavelet transform computed by \texttt{wd}.

**Value**

A vector of the extracted coefficients.

**Author(s)**

G P Nason

**References**

Nason, G.P. and Silverman, B.W. The stationary wavelet transform and some statistical applications.
addpkt

See Also

\texttt{wst}, \texttt{wst.object}, \texttt{accessD}, \texttt{getpacket.wst}

Examples

\begin{verbatim}
# # Get the 4th level of mother wavelet coefficients from a decomposition
#
dat <- rnorm(128)
accessD(wst(dat), level=4)
\end{verbatim}

addpkt \hspace{1cm} \textit{Add a wavelet packet box to an already set up time-frequency plot}

Description

This function assumes that a high-level plot has already been set up using \texttt{plotpkt}. Given that this function plots a wavelet packet box at a given level, packet index and with particular shading and color and optionally plotting a sequence of coefficients at that location rather than a shaded box.

Usage

\begin{verbatim}
addpkt(level, index, density, col, yvals)
\end{verbatim}

Arguments

\begin{itemize}
  \item \texttt{level} The level at which the box or yvals are plotted
  \item \texttt{index} The packet index at which the box of yvals are plotted
  \item \texttt{density} The density of the shading of the box
  \item \texttt{col} The color of the box
  \item \texttt{yvals} If this argument is missing then a shaded coloured box is drawn, otherwise a time series of \texttt{yvals} is plotted where the box would have been.
\end{itemize}

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

\texttt{basisplot}, \texttt{basisplot.BP}, \texttt{basisplot.wp}, \texttt{plotpkt}, \texttt{plot.nvwp}
AutoBasis

*Run Coifman-Wickerhauser best basis algorithm on wavelet packet object*

**Description**

Runs the Coifman-Wickerhauser best basis algorithm on a wavelet packet object. Packets not in the basis are replaced by vectors of NAs. Superseded by the MaNoVe functions.

**Details**

Superseded by the MaNoVe functions (which run in C code).

**Value**

A wp class object which contains the select basis. All packets that are not in the basis get replaced by vectors of NAs.

**Author(s)**

G P Nason

**See Also**

MaNoVe

---

av.basis

*Perform basis averaging for wst class object*

**Description**

**Note:** that this function is not for direct user use. This function is a helper routine for the AvBasis.wst function which is the one that should be used by users.

This function works by recursion, essentially it merges the current levels C coefficients from one packet shift with its associated D coefficients, does the same for the other packet shift and then averages the two reconstructions to provide the C coefficients for the next level up.

**Usage**

```
av.basis(wst, level, ix1, ix2, filter)
```
**AvBasis**

**Arguments**

- `wst` The `wst.object` that you wish to basis average
- `level` The resolution level the function is currently operating at
- `ix1` Which "left" packet in the level you are accessing
- `ix2` Which "right" packet
- `filter` The wavelet filter details, see `filter.select`

**Details**

Description says all, see help page for `AvBasis.wst`.

**Value**

Returns the average basis reconstruction of a `wst.object`.

**Author(s)**

G P Nason

**See Also**

`AvBasis, AvBasis.wst, conbar, rotateback, getpacket`

---

**AvBasis**

*Basis averaging ("inversion")*

**Description**

Average of whole collection of basis functions.

This function is generic.

Particular methods exist. For the `wst` class object this generic function uses `AvBasis.wst`. In the future we hope to add methods for `wp` and `wpst` class objects.

**Usage**

`AvBasis(...)`

**Arguments**

... See individual help pages for details

**Details**

See individual method help pages for operation and examples.
Value

A vector containing the average of the representation over all bases.

RELEASE

Version 3.6.0 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

wst, wst.object, AvBasis.wst

---

AvBasis.wst

Perform basis averaging for (packet-ordered) non-decimated wavelet transform.

Description

Perform basis averaging for (packet-ordered) non-decimated wavelet transform.

Usage

```r
## S3 method for class 'wst'
AvBasis(wst, Ccode=TRUE, ...)
```

Arguments

- `wst`: An object of class `wst` that contains coefficients of a packet ordered non-decimated wavelet transform (e.g. produced by the `wst` function.
- `Ccode`: If TRUE then fast compiled C code is used to perform the transform. If FALSE then S code is used. Almost always use the default TRUE option. (It is conceivable that some implementation can not use the C code and so this option permits use of the slower S code).
- `...`: any other arguments

Details

The packet-ordered non-decimated wavelet transform computed by `wst` computes the coefficients of an input vector with respect to a library of all shifts of wavelet basis functions at all scales. Here "all shifts" means all integral shifts with respect to the finest scale coefficients, and "all scales" means all dyadic scales from 0 (the coarsest) to J-1 (the finest) where \(2^J = n\) where \(n\) is the number of data points of the input vector. As such the packet-ordered non-decimated wavelet transform contains a library of all possible shifted wavelet bases.
Basis selection. It is possible to select a particular basis and invert that particular representation. In WaveThresh a basis is selected by creating a \texttt{nv (node.vector)} class object which identifies the basis. Then the function \texttt{InvBasis} takes the wavelet representation and the node.vector and inverts the representation with respect to the selected basis. The two functions \texttt{MaNoVe} and \texttt{numtonv} create a node.vector: the first by using a Coifman-Wickerhauser minimum entropy best-basis algorithm and the second by basis index.

**Basis averaging.** Rather than select a basis it is often useful to preserve information from all of the bases. For examples, in curve estimation, after thresholding a wavelet representation the coefficients are coefficients of an estimate of the truth with respect to all of the shifted basis functions. Rather than select one of them we can average over all estimates. This sometimes gives a better curve estimate and can, for examples, get rid of Gibbs effects. See Coifman and Donoho (1995) for more information on how to do curve estimation using the packet ordered non-decimated wavelet transform, thresholding and basis averaging.

Further it might seem that inverting each wavelet transform and averaging might be a computationally expensive operation: since each wavelet inversion costs order \(n\) operations and there are \(n\) different bases and so you might think that the overall order is \(n^2\). It turns out that since many of the coarser scale basis functions are duplicated between bases there is redundancy in the non-decimated transform. Coifman and Donoho’s TI-denoising algorithm makes use of this redundancy which results in an algorithm which only takes order \(n \log n\) operations.

For an examples of denoising using the packet-ordered non-decimated wavelet transform and basis averaging see Johnstone and Silverman, 1997. The WaveThresh implementation of the basis averaging algorithm is to be found in Nason and Silverman, 1995.

**Value**

A vector containing the average of the wavelet representation over all the basis functions. The length of the vector is \(2^n\) where \(n\) is the number of levels in the input \texttt{wst} object.

**RELEASE**

Version 3.6.0 Copyright Guy Nason 1995

**Author(s)**

G P Nason

**See Also**

\texttt{av.basis, wst, wst.object, MaNoVe, numtonv, InvBasis, wavegrow}

**Examples**

```
# Generate some test data
#
test.data <- example.1()$y
#
# Now take the packet-ordered non-decimated wavelet transform
#```
tdwst <- wst(test.data)
#
# Now "invert" it using basis averaging
#
tdwstAB <- AvBasis(tdwst)
#
# Let's compare it to the original
#
sum( (tdwstAB - test.data)^2)
#
# [1] 9.819351e-17
#
# Very small. They're essentially same.
#
# See the threshold.wst help page for an
# an examples of using basis averaging in curve estimation.

---

AvBasis.wst2D

Perform basis averaging for (packet-ordered) 2D non-decimated wavelet transform.

**Description**

Perform basis averaging for (packet-ordered) 2D non-decimated wavelet transform.

**Usage**

## S3 method for class 'wst2D'

AvBasis(wst2D, ...)

**Arguments**

- **wst2D**
  An object of class `wst2D` that contains coefficients of a packet ordered 2D non-decimated wavelet transform (e.g. produced by the `wst2D` function.

- **...**
  any other arguments

**Details**

The packet-ordered 2D non-decimated wavelet transform computed by `wst2D` computes the coefficients of an input matrix with respect to a library of all shifts of wavelet basis functions at all scales. Here "all shifts" means all integral shifts with respect to the finest scale coefficients with shifts in both the horizontal and vertical directions, and "all scales" means all dyadic scales from 0 (the coarsest) to J-1 (the finest) where $2^J = n$ where $n$ is the dimension of the input matrix. As such the packet-ordered 2D non-decimated wavelet transform contains a library of all possible shifted wavelet bases.

**Basis averaging.** Rather than select a basis it is often useful to preserve information from all of the bases. For examples, in curve estimation, after thresholding, the coefficients are coefficients of an estimate of the truth with respect to all of the shifted basis functions. Rather than select one of
them we can average over all estimates. This sometimes gives a better curve estimate and can, for
elements, get rid of Gibbs effects. See Coifman and Donoho (1995) for more information on how
to do curve estimation using the packet ordered non-decimated wavelet transform, thresholding and
basis averaging. See Lang et al. (1995) for further details of surface/image estimation using the 2D
non-decimated DWT.

Value

A square matrix of dimension $2^\text{levels}$ containing the average-basis “reconstruction” of the
wst2D object.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

wst2D, wst2D.object

Examples

# Generate some test data
#
#test.data <- matrix(rnorm(16), 4,4)
#
# Now take the 2D packet ordered DWT
#
#tdwst2D <- wst2D(test.data)
#
# Now "invert" it using basis averaging
#
#tdwstAB <- AvBasis(tdwst2D)
#
# Let's compare it to the original
#
#sum((tdwstAB - test.data)^2)
#
# [1] 1.61215e-17
#
# Very small. They're essentially same.
**BabyECG**

*Physiological data time series.*

**Description**

Two linked medical time series containing 2048 observations sampled every 16 seconds recorded from 21:17:59 to 06:27:18. Both these time series were recorded from the same 66 day old infant by Prof. Peter Fleming, Dr Andrew Sawczenko and Jeanine Young of the Institute of Child Health, Royal Hospital for Sick Children, Bristol. BabyECG, is a record of the infant’s heart rate (in beats per minute). BabySS is a record of the infant’s sleep state on a scale of 1 to 4 as determined by a trained expert monitoring EEG (brain) and EOG (eye-movement). The sleep state codes are 1=quiet sleep, 2=between quiet and active sleep, 3=active sleep, 4=awake.

**Format**

The BabyECG time series is a nice examples of a non-stationary time series whose spectral (time-scale) properties vary over time. The function `ewspect` can be used to analyse this time series to inspect the variation in the power of the series over time and scales.

The BabySS time series is a useful independent time series that can be associated with changing power in the BabyECG series. See the discussion in Nason, von Sachs and Kroisandt.

**RELEASE**

Version 3.9 Copyright Guy Nason 1998

**SEE ALSO**

`ewspect`

**Author(s)**

G P Nason

**Source**

Institute of Child Health, Royal Hospital for Sick Children, Bristol.

**References**

Examples

```r
data(BabyECG)
data(BabySS)
#
# Plot the BabyECG data with BabySS overlaid
#
# Note the following code does some clever scaling to get the two
# time series overlaid.
#
myhrs <- c(22, 23, 24, 25, 26, 27, 28, 29, 30)
mylab <- c("22", "23", "00", "01", "02", "03", "04", "05", "06")
initsecs <- 59 + 60 * (17 + 60 * 21)
mysecs <- (myhrs * 3600)
secsat <- (mysecs - initsecs)/16
mxy <- max(BabyECG)
mny <- min(BabyECG)
ro <- range(BabySS)
rc <- 0:4

## Not run: plot(1:length(BabyECG), BabyECG, xaxt = "n", type = "l", xlab = "Time (hours)", ylab = "Heart rate (beats per minute)")
## End(Not run)

## Not run: lines(1:length(BabyECG), no, lty = 3)
## Not run: axis(1, at = secsat, labels = mylab)
## Not run: axis(4, at = nc, labels = as.character(rc))
#
# Sleep state is the right hand axis
#
#
Physiological data time series.

Description

Two linked medical time series containing 2048 observations sampled every 16 seconds recorded from 21:17:59 to 06:27:18. Both these time series were recorded from the same 66 day old infant by Prof. Peter Fleming, Dr Andrew Sawczenko and Jeanine Young of the Institute of Child Health, Royal Hospital for Sick Children, Bristol. BabyECG, is a record of the infant’s heart rate (in beats per minute). BabySS is a record of the infant’s sleep state on a scale of 1 to 4 as determined by a trained expert monitoring EEG (brain) and EOG (eye-movement). The sleep state codes are 1=quiet sleep, 2=between quiet and active sleep, 3=active sleep, 4=awake.

Format

The BabyECG time series is a nice examples of a non-stationary time series whose spectral (time-scale) properties vary over time. The function ewsdp can be used to analyse this time series to inspect the variation in the power of the series over time and scales.

The BabySS time series is a useful independent time series that can be associated with changing power in the BabyECG series. See the discussion in Nason, von Sachs and Kroisandt.

RELEASE

Version 3.9 Copyright Guy Nason 1998

SEE ALSO

ewsdp

Author(s)

G P Nason

Source

Institute of Child Health, Royal Hospital for Sick Children, Bristol.

References

Examples

data(BabyECG)
data(BabySS)
#
# Plot the BabyECG data with BabySS overlaid
#
# Note the following code does some clever scaling to get the two
# time series overlaid.
#
myhrs <- c(22, 23, 24, 25, 26, 27, 28, 29, 30)
mylab <- c("22", "23", "00", "01", "02", "03", "04", "05", "06")
initsecs <- 59 + 60 * (17 + 60 * 21)
mysecs <- (myhrs * 3600)
secsat <- (mysecs - initsecs)/16
mxy <- max(BabyECG)
mny <- min(BabyECG)
ro <- range(BabySS)
rc <- 0:4
## Not run: plot(1:length(BabyECG), BabyECG, xaxt = "n", type = "l", xlab = "Time (hours)", ylab = "Heart rate (beats per minute)")
## End(Not run)
## Not run: lines(1:length(BabyECG), no, lty = 3)
## Not run: axis(1, at = secsat, labels = mylab)
## Not run: axis(4, at = nc, labels = as.character(rc))
#
# Sleep state is the right hand axis
#
basisplot

Generic basis plot function

Description
Plots a representation of a time-frequency plane and then plots the locations, and sometimes time series representations of coefficients, for the packets in the basis.

Usage
basisplot(x, ...)

Arguments
x basis to plot
... various arguments to methods

Details
Description says all

Value
Nothing, usually

Author(s)
G P Nason

See Also
basisplot.BP, basisplot.wp
Description

The x objects store basis information obtained through the `makewpstDO` object. This function plots where the basis packets are on the time frequency plane.

Usage

```r
## S3 method for class 'BP'
basisplot(x, num=min(10, length(BP$level)), ...)
```

Arguments

- `x` The BP class object, possibly coming from the BP component of the object returned by `makewpstDO` that you wish to plot
- `num` The number of packets that you wish to add to the plot
- `...` Other arguments

Details

Description says all

Value

Nothing of note

Author(s)

G P Nason

See Also

`makewpstDO`, `Best1DCols`

Examples

```r
#
# See example in help for \code{\link{makewpstDO}}
#
```
Function to graphically select a wavelet packet basis

Description

Note, one or two (depending on the state of draw.mode) graphics windows with mouse-clickable interfaces have to open to use this function.

Graphically select a wavelet packet basis associated with a wavelet packet object. Left-click selects packets, right click exits the routine.

Usage

```r
## S3 method for class 'wp'
basisplot(x, draw.mode=FALSE, ...)
```

Arguments

- `x` : The `wp.object` for which you wish to select a basis graphically for.
- `draw.mode` : If TRUE then TWO graphics windows have to be open. Every time a packet is selected in the packet selection window, a representation of the wavelet packet basis function is drawn in the other window
- `...` : Other arguments

Details

A wavelet packet basis described in WaveThresh using the node vector object (class from `MaNoVe.wp`) which for wavelet packets is `nvwp`. This function takes a `wp.object` object and graphically depicts all possible basis function locations. The user is then invited to click on different packets, these change colour. When finished, the user right clicks on the graphic and the selected basis is returned.

**Note that the routine does not check to see whether the basis is legal. You have to do this.** A legal basis can select packets from different levels, however you can’t select packets that both cover the same packet index, however every packet index has to be covered.

A better function would check basis legality!

Value

An object of class `nvwp` which contains the specification for the basis.

Author(s)

G P Nason

See Also

`addpkt`, `InvBasis`, `MaNoVe.wp`, `plotpkt`, `wp`
Bayesian wavelet thresholding.

**Description**

This function carries out Bayesian wavelet thresholding of noisy data, using the BayesThresh method of Abramovich, Sapatinas, & Silverman (1998).

**Usage**

```r
BAYES.THR(data, alpha = 0.5, beta = 1, filter.number = 8, family = "DaubLeAsymm", bc = "periodic", dev = var, j0 = 5, plotfn = FALSE)
```

**Arguments**

- **data**
  A vector of length a power of two, containing noisy data to be thresholded.

- **alpha, beta**
  Hyperparameters which determine the priors placed on the wavelet coefficients. Both alpha and beta take positive values; see Abramovich, Sapatinas, & Silverman (1998) or Chipman & Wolfson (1999) for more details on selecting alpha and beta.

- **filter.number**
  This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments. For the “wavelets on the interval” (bc="interval") transform the filter number ranges from 1 to 8. See the table of filter coefficients indexed after the reference to Cohen, Daubechies and Vial, (1993).

- **family**
  Specifies the family of wavelets that you want to use. Two popular options are "DaubExPhase" and "DaubLeAsymm" but see the help for `filter.select` for more possibilities.
  This argument is ignored for the “wavelets on the interval” transform (bc="interval").

- **bc**
  Specifies the boundary handling. If bc="periodic" the default, then the function you decompose is assumed to be periodic on it’s interval of definition, if bc="symmetric" then the function beyond its boundaries is assumed to be a symmetric reflection of the function in the boundary. The symmetric option was the implicit default in releases prior to 2.2. If bc="interval" then the “wavelets on the interval algorithm” due to Cohen, Daubechies and Vial is used. (The WaveThresh implementation of the “wavelets on the interval transform” was coded by Piotr Fryzlewicz, Department of Mathematics, Wroclaw University of Technology, Poland; this code was largely based on code written by Markus Monnerjahn, RHRK, Universitat Kaiserslautern; integration into WaveThresh by GPN).

- **dev**
  This argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the `var()` function. A popular, useful and robust alternative is the `madmad` function.
The primary resolution level. While BayesThresh thresholds at all resolution levels, \( j_0 \) is used in assessing the universal threshold which is used in the empirical Bayes estimation of hyperparameters.

If TRUE, BAYES.THR draws the noisy data and the thresholded function estimate.

A mixture prior consisting of a zero-mean normal distribution and a point mass at zero is placed on each wavelet coefficient. The empirical coefficients are then calculated and the priors updated to give posterior distributions for each coefficient. The thresholded value of each coefficient is the median of that coefficient’s posterior distribution. See Abramovich, Sapatinas, & Silverman (1998) for more details of the procedure; the help page for threshold.wd has more information about wavelet thresholding in general.

The function wave.band uses the same priors to compute posterior credible intervals for the regression function, using the method described by Barber, Nason, & Silverman (2001).

A vector containing the thresholded estimate of the function from which the data was drawn.

3.9.5 Code by Fanis Sapatinas/Felix Abramovich Documentation by Stuart Barber

G P Nason

threshold.wd, wd

# Generate some noisy test data and plot it.
# blocks.data <- DJ.EX(n=512, noisy=TRUE)$blocks
# Now try BAYES.THR with the default parameters.
# blocks.thr <- BAYES.THR(blocks.data, plotfn=TRUE)
# The default wavelet is Daubechies' least asymmetric wavelet
# with 8 vanishing moments; quite a smooth wavelet. Since the
# flat sections are still rather noisy, try Haar wavelets:
# blocks.thr <- BAYES.THR(blocks.data, plotfn=TRUE, filter.number=1,
# family = "DaubExPhase")
To show the importance of a sensible prior, consider alpha = 4,
# beta = 1 (which implies a smoother prior than the default).
blocks.thr <- BAYES.THR(blocks.data, plotfn=TRUE, filter.number=1,
                       family = "DaubExPhase", alpha=4, beta=1)
# Here, the extreme values of the function are being smoothed towards zero.
#

Best1DCols

Extract the best (one-dimensional) nondecimated WP packets

Description

This function takes the whole set of nondecimated wavelet packets and selects those packets that
 correlate best with the "response" groups. The idea is to reduce the large dimensionality (number
 of packets) into something more manageable which can then be fed into a proper discriminator.

Usage

Best1DCols(w2d, mincor= 0.69999999999999996)

Arguments

- w2d: An object that gets returned from a call to the wpst2discr function which turns
   a wpst class object into a regular multivariate matrix
- mincor: The threshold above which variables (packets) get included into the final mix if
   their correlation with the groups variable is higher than this value.

Details

This function is not intended for direct user use. In this function, the w2d object contains a matrix
where each column contains the coefficients of a single packet from a non-decimated wavelet packet
transform. The number of rows of the matrix is the same as the original time series and hence each
column can be correlated with a separate groups variable that contains the group membership of a
separate variable which changes over time. Those packet columns that have correlation greater than
the mincor value are extracted and returned in the BasisMatrix item of the returned list.

Value

A list with the following components:

- nlevelsWT: The number of levels of the nondecimated wavelet packet encapsulator, w2d
- BasisMatrix: The highest correlating packets, sorted according to decreasing correlation
- level: The levels corresponding to the selected packets
- pkt: The packet indices corresponding to the selected packets
- basiscoef: The sorted correlations
- groups: The groups time series
bestm

Function called by makewpstRO to identify which packets are individually good for correlating with a response

Description

This function is used when you have a huge number of packets where you want to identify which ones are, individually, candidates for the good prediction of a response.

Usage

bestm(w2mobj, y, percentage = 50)

Arguments

- **w2mobj**: The w2m object that contains the packets you wish to preselect
- **y**: The response time series
- **percentage**: The percentage of the w2m packets that you wish to select

Details

This function naively addresses a very common problem. The object w2mobj contains a huge number of variables which might shed some light on the response object y. The problem is that the dimensionality of w2mobj is larger than that of the length of the series y.

The solution here is to choose a large, but not huge, subset of the variables that might be potentially useful in correlating with y, discard the rest, and return the "best" or preselected variables. Then the dimensionality is reduced and more sophisticated methods can be used to perform better quality modelling of the response y on the packets in w2mobj.

Value

A list of class w2m with the following components:

- **m**: A matrix containing the select packets (as columns), reordered so that the best packets come first
- **ixvec**: A vector which indexes the best packets into the original supplied matrix
- **pktix**: The original wavelet packet indices corresponding to each packet
- **level**: As pktix but for the wavelet packet levels
- **nlevelsWT**: The number of resolution levels in the original wavelet packet object
- **cv**: The ordered correlations
BMdiscr

Author(s)
G P Nason

See Also
makewpstRO

BMdiscr  Subsidiary routine for makewpstDO function

Description
Function actually performs discrimination on reduced variable set supplied to it from Best1DCols function.

Usage
BMdiscr(BP)

Arguments
BP  An list of the same format as returned by Best1DCols

Details
Not intended for direct user use

Value
Returns a list of objects: essentially the input argument BP and the return value from a call to the lda function which performs the discrimination operation.

Author(s)
G P Nason

See Also
Best1DCols,makewpstDO
c2to4

Take integer, represent in binary, then think of and return that representation in base 4

Description

Not designed, or really useful, for casual user use!

For example: take the integer 5. In binary this is 101. Then, this representation in base 4 is 16+1 = 17.

This function is used by accessD.wpst to help it access coefficients.

Usage

c2to4(index)

Arguments

index The integer you wish to convert

Details

Description says all

Value

The converted number

Author(s)

G P Nason

See Also

accessD.wpst

Examples

c2to4(5)
CanUseMoreThanOneColor

Deprecated function

Description
Not used any more. This function used to interrogate the display device to see whether more than one color could be used. The function is set to return true whether or not the display device actually has this capability. It is used in the `plot.wp` function.

Usage

CanUseMoreThanOneColor()

Details
Description says it all.

Value
This function always returns TRUE

Author(s)
G P Nason

See Also

plot.wp

checkmyews

Check a LSW spectrum through repeated simulation and empirical averages

Description
Given a LSW spectrum this function simulates `nsim` realizations, estimates the spectrum, and then averages the results. The large sample averages should converge to the original spectrum.

Usage

checkmyews(spec, nsim=10)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>spec</td>
<td>The LSW spectrum</td>
</tr>
<tr>
<td>nsim</td>
<td>The number of realizations</td>
</tr>
</tbody>
</table>
Value
A LSW spectrum obtained as the average of nsim simulations from the spec spectrum.

Author(s)
G P Nason

See Also
cns.LSWsim, ewspec

Description
A subsidiary routine for denproj. Not intended for direct user use.

Usage
Chires5(x, tau=1, J, filter.number=10, family="DaubLeAsymm", nT=20)

Arguments
- **x**: The data (random sample for density estimation)
- **tau**: Fine tuning parameter
- **J**: Resolution level
- **filter.number**: The smoothness of the wavelet, see filter.select
- **family**: The family of the wavelet, see family
- **nT**: The number of iterations in the Daubechies-Lagarias algorithm

Details
As description

Value
A list with the following components:
- **coef**: The scaling function coefficients
- **klim**: The integer translates of the scaling functions used
- **p**: The primary resolution, calculated in code as tau*2^J
- **filter**: The usual filter information, see filter.select
- **n**: The length of the data x
- **res**: A list containing components: p, as above, tau as input and J as above. This summarizes the resolution information
Chires6

Author(s)
David Herrick

See Also
Chires6, denproj

Chires6
Subsid routine for denproj (calcs scaling function coefs with cov)

Description
Function is essentially the same as Chires5 but also returns covariances between coefficients. A subsidiary routine for denproj. Not intended for direct user use.

Usage
Chires6(x, tau=1, J, filter.number=10, family="DaubLeAsymm", nT=20)

Arguments
x The data (random sample for density estimation)
taxu Fine tuning parameter
J Resolution level
filter.number The smoothness of the wavelet, see filter.select
family The family of the wavelet, see family
nT The number of iterations in the Daubechies-Lagarias algorithm

Details
As description

Value
A list with the following components:

coeff The scaling function coefficients
covar The coefficients’ covariance matrix
klim The integer translates of the scaling functions used
p The primary resolution, calculated in code as tau*2^J
filter The usual filter information, see filter.select
n The length of the data x
res A list containing components: p, as above, tau as input and J as above. This summarizes the resolution information
cns

Create new zeroed spectrum.

Description

Part of a two-stage function suite designed to simulate locally stationary wavelet processes in conjunction with the LSWsim function.

Usage

```r
cns(n, filter.number=1, family="DaubExPhase")
```

Arguments

- `n` The length of the simulated process that you want to produce. Must be a power of two (for this software).
- `filter.number` This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.
- `family` specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

Details

This simple routine merely computes the time-ordered non-decimated wavelet transform of a zero vector of the same length as the eventual simulated series that you wish to produce.

If you look at this routine you will see that it is extremely simple. First, it checks to see whether the `n` that you supplied is a power of two. If it is then it creates a zero vector of that length. This is then non-decimated wavelet transformed with the appropriate wavelet.

The output can then be processed and then finally supplied to LSWsim for process simulation.

Value

An object of class: `wd`, and, in fact, of the non-decimated variety. All wavelet coefficients of this are zero.

Author(s)

G P Nason
**compare.filters**  
Compares two filters.

**Description**

Compares two filters (such as those returned from `filter.select`). This function returns TRUE if they are the same otherwise returns FALSE.

**Usage**

```r
compare.filters(f1, f2)
```

**Arguments**

- `f1` Filter, such as that returned by `filter.select`
- `f2` Filter, such as that returned by `filter.select`

**Details**

A very simple function. It only needs to check that the family and filter.number components of the filter are the same.

**Value**

If `f1` and `f2` are the same the function returns TRUE, otherwise it returns FALSE.

**RELEASE**

Version 3.9 Copyright Guy Nason 1998

**Author(s)**

G P Nason

**See Also**

`filter.select`
Examples

# Create three filters!
#
filt1 <- filter.select(4, family="DaubExPhase")
filt2 <- filter.select(3, family="DaubExPhase")
filt3 <- filter.select(4, family="DaubeAsymm")
#
# Now let us see if they are the same...
#
compare.filters(filt1, filt2)
# [1] FALSE
compare.filters(filt1, filt3)
# [1] FALSE
compare.filters(filt2, filt3)
# [1] FALSE
#
# Nope, (what a surprise) they weren't. How about
#
compare.filters(filt1, filt1)
# [1] TRUE
#
# Yes, they were the same!

---

compgrot: *Compute empirical shift for time ordered non-decimated transforms.*

Description

Computes the empirical shift required for time-ordered non-decimated transform coefficients to bring them into time order.

Usage

```r
compgrot(J, filter.number, family)
```

Arguments

- **J**: The number of levels in the non-decimated transform where coefficients are to be time-aligned.
- **filter.number**: The wavelet filter number to be used, see `filter.select`.
- **family**: The wavelet family, see `filter.select`.

Details

Time-ordered non-decimated transform coefficients when raw are not in exact time alignment due to the phase of the underlying wavelet. This function returns the shifts that are necessary to apply to each resolution level in the transform to bring back each set of time-ordered coefficients into
time alignment. Note that the shifts returned are approximate shifts which work for any Daubechies wavelet. More accurate shifts can be computed using detailed knowledge of the particular wavelet used.

Each shift is "to the left". I.e. higher indexed coefficients should take the place of lower-indexed coefficients. Periodic boundaries are assumed.

This realignment is mentioned in Walden and Contreras Cristan, (1997) and Nason, Sapatinas and Sawczenko, (1998).

Value

A vector containing the shifts that need to be applied to each scale level to return them to the correct time alignment.

There are J entries in the vector. The first entry corresponds to the shift required for the finest level coefficients (i.e. level J-1) and the last entry corresponds to the coarsest level (i.e. level 0). Entry j corresponds to the shift required for scale level J-j.

RELEASE

Version 3.6 Copyright Guy Nason 1997

Note

GROT was the shop started by Reginald Perrin. Unfortunately, GROT stands for "Guy ROTation".

Author(s)

G P Nason

See Also

wst, wst.object, wpst, wpst.object.

Examples

# Let's see how the resolution levels have to be shifted
#
compgrot(4, filter.number=10, family="DaubExPhase")
#[1]  2  6 15 31
#
# In other words. Scale level 3 needs to be shifted two units.
# Scale level 2 needs to be shifted 6 units
# Scale level 1 needs to be shifted 15 units
# Scale level 0 needs to be shifted 31 units.
Compress objects

Description

Compress objects.

This function is generic.

Particular methods exist. For the \texttt{imwd} class object this generic function uses \texttt{compress.imwd}. There is a default compression method: \texttt{compress.default} that works on vectors.

Usage

\texttt{compress(...)}

Arguments

\dots \quad \text{See individual help pages for details.}

Details

See individual method help pages for operation and examples

Value

A compressed version of the input.

RELEASE

Version 2.0 Copyright Guy Nason 1993

Author(s)

G P Nason

See Also

\texttt{compress.default,compress.imwd,imwd,imwd.object,imwdc.object,threshold.imwd}
Do "zero" run-length encoding compression of a vector of numbers.

Description

Efficiently compress a vector containing many zeroes.

Usage

```r
## Default S3 method:
compress(v, verbose=FALSE,...)
```

Arguments

- `v` The vector that you wish to compress. This compression function is efficient at compressing vectors with many zeroes, but is not a general compression routine.
- `verbose` If `TRUE` then this routine prints out the degree of compression achieved.
- `...` any other arguments

Details

Images are large objects. Thresholded 2d wavelet objects (`imwd`) are also large, but many of their elements are zero. `compress.default` takes a vector, decides whether compression is necessary and if it is makes an object of class `compressed` containing the nonzero elements and their position in the original vector.

The decision whether to compress the vector or not depends on two things, first the number of non-zero elements in the vector (`r`, say), and second the length of the vector (`n`, say). Since the position and value of the non-zero elements is stored we will need to store `2r` values for the non-zero elements. So compression takes place if `2r < n`.

This function is the default method for the generic function `compress`. It can be invoked by calling `compress` for an object of the appropriate class, or directly by calling `compress.default` regardless of the class of the object.

Value

An object of class `compressed` if compression took place, otherwise a an object of class `uncompressed`.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Note

Sometimes the compressed object can be larger than the original. This usually only happens for small objects, so it doesn’t really matter.
Author(s)

G P Nason

See Also

compress.imwd, threshold.imwd, uncompress

Examples

# Compress a vector with lots of zeroes
#
compress(c(rep(0,100),99))
#$position:
# [1] 101
#
#$values:
# [1] 99
#
#$original.length:
# [1] 101
#
#attr(, "class"):
# [1] "compressed"
#
# Try to compress a vector with not many zeroes
#
compress(1:10)
#$vector:
# [1] 1 2 3 4 5 6 7 8 9 10
#
#attr(, "class"):
# [1] "uncompressed"
#
#
conbar

Arguments

x Object to compress. Compression only does anything on thresholded \texttt{imwd.object}.
verbose If this is true then report on compression activity.
... any other arguments

Details

Thresholded \texttt{imwd} objects are usually very large and contain many zero elements. This function compresses these objects into smaller \texttt{imwd} objects by using the \texttt{compress.default} function which removing the zeroes. This function is a method for the generic function \texttt{compress} for class \texttt{imwd} objects. It can be invoked by calling \texttt{compress} for an object of the appropriate class, or directly by calling \texttt{compress.imwd} regardless of the class of the object.

Value

An object of type "\texttt{imwdc}" representing the compressed \texttt{imwd} object.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

\texttt{compress, compress.default, imwd, imwd.object, imwdc.object, threshold.imwd}.

Examples

```r
# The user shouldn't need to use this function directly as the
# \code{\link{threshold.imwd}) function calls it
# automatically.
#
conbar
```

Description

Wrapper to the C function \texttt{conbar} which is the main function in WaveThresh to do filter convolution/reconstruction with data. Although users use the \texttt{wr} function to perform a complete inverse discrete wavelet transform (DWT) this function repeatedly uses the \texttt{conbar} routine, once for each level to reconstruct the next finest level. The C \texttt{conbar} routine is possibly the most frequently utilized by WaveThresh.
Usage

conbar(c.in, d.in, filter)

Arguments

- **c.in**: The father wavelet coefficients that you wish to reconstruct in this level’s convolution.
- **d.in**: The mother wavelet coefficients that you wish to reconstruct in this level’s convolution.
- **filter**: A given filter that you wish to use in the level reconstruction. This should be the output from the `filter.select` function.

Details

The `wr` function performs the inverse wavelet transform on an `wd.object` class object. Internally, the `wr` function uses the C `conbar` function. Other functions also make use of `conbar` and some R functions also would benefit from using the fast C code of the `conbar` reconstruction hence this WaveThresh function. Some of the other functions that use `conbar` are listed in the SEE ALSO section. Many other functions call C code that then uses the C version of `conbar`.

Value

A vector containing the reconstructed coefficients.

Author(s)

G P Nason

See Also

- `av.basis`
- `InvBasis.wp`
- `wr`

Examples

```r
# Let's generate some test data, just some 32 normal variates.
#
v <- rnorm(32)
#
# Now take the wavelet transform with default filter arguments (which
# are filter.number=10, family="DaubLeAsymm")
#
vwd <- wd(v)
#
# Now, let's take an arbitrary level, say 2, and reconstruct level 3
# scaling function coefficients
#
c.in <- accessC(vwd, lev=2)
d.in <- accessD(vwd, lev=2)
```
convert

### Description

Convert one type of wavelet object into another.

This function is generic.

Particular methods exist:

* `convert.wd` is used to convert non-decimated `wd` objects into `wst` objects. `convert.wst` is used to convert `wst` objects into non-decimated `wd` objects.

### Usage

```r
convert(...)```

### Arguments

... See individual help pages for details.

### Details

See individual method help pages for operation and examples.

### Value

An object containing the converted representation.

### RELEASE

Version 3.6.0 Copyright Guy Nason 1995
**Author(s)**

G P Nason

**See Also**

convert.wd, convert.wst, wst, wst.object, wst_object.

---

**convert.wd**

*Convert a non-decimated wd object into a wst object.*

**Description**

Convert a time-ordered non-decimated wavelet transform object into a packet-ordered non-decimated wavelet transform object.

**Usage**

```r
## S3 method for class 'wd'
convert(wd, ...)
```

**Arguments**

- `wd` The `wd` class object that you wish to convert.
- `...` any other arguments

**Details**

In WaveThresh3 a non-decimated wavelet transform can be ordered in two different ways: as a time-ordered or packet-ordered representation. The coefficients in the two objects are *exactly the same* it is just their internal representation and ordering which is different. The two different representations are useful in different situations. The packet-ordering is useful for curve estimation applications and the time-ordering is useful for time series applications.

See Nason, Sapatinas and Sawczenko, 1998 for further details on ordering and weaving.

Note that the input object must be of the non-decimated type. In other words the type component of the input object must BE "station". Once the input object has been converted the output can be used with any of the functions suitable for the `wst.object`.

The `getarrvec` function actually computes the permutation to weave coefficients from one ordering to another.

**Value**

An object of class `wst` containing exactly the same information as the input object but ordered differently as a packet-ordered object.

**RELEASE**

Version 3.6 Copyright Guy Nason 1997
Author(s)

G P Nason

See Also

convert, getarrvec, levarr, wd, wd.object, wst, wst.object.

Examples

```r
# Generate a sequence of 32 random normals (say) and take their
time-ordered non-decimated wavelet transform
#
myrand <- wd(rnorm(32), type="station")
#
# Print out the result (to verify the class and type of the object)
#
myrand

#Class 'wd': Discrete Wavelet Transform Object:
#   ~~ : List with 8 components with names
#   C D nlevelsWT fl.dbase filter type bc date
#
#$ C and $ D are LONG coefficient vectors!
#
#Created on: Tue Sep 29 12:17:53 1998
#Type of decomposition: station
#
#summary(.):
#----------
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
#Boundary handling: periodic
#Transform type: station
#Date: Tue Sep 29 12:17:53 1998
#
# Yep, the myrand object is of class: \link{wd.object}).
#
# Now let's convert it to class \link{wst}. The object
# gets returned and, as usual in S, is printed.
#
convert(myrand)

#Class 'wst': Stationary Wavelet Transform Object:
#   \\: List with 5 components with names
#   wp Carray nlevelsWT filter date
#
#$wp and $Carray are the coefficient matrices
#
#Created on: Tue Sep 29 12:17:53 1998
#
#summary(.):
#----------
```
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
#Date: Tue Sep 29 12:17:53 1998
# Yes. The returned object is of class \code{\link{wst.object}}.
# I.e. it has been converted successfully.

---

**convert.wst**  
*Convert a non-decimated wst object into a wd object.*

### Description

Convert a packed-ordered non-decimated wavelet transform object into a time-ordered non-decimated wavelet transform object.

### Usage

```r
## S3 method for class 'wst'
convert(wst, ...)
```

### Arguments

- `wst`  
The wst class object that you wish to convert.
- `...`  
any other arguments

### Details

In WaveThresh3 a non-decimated wavelet transform can be ordered in two different ways: as a time-ordered or packet-ordered representation. The coefficients in the two objects are *exactly the same* it is just their internal representation and ordering which is different. The two different representations are useful in different situations. The packet-ordering is useful for curve estimation applications and the time-ordering is useful for time series applications.

See Nason, Sapatinas and Sawczenko, 1998 for further details on ordering and weaving.

Note that the input object must be of the non-decimated type. In other words the type component of the input object must be "station". Once the input object has been converted the output can be used with any of the functions suitable for the wd.object.

The actual weaving permutation for shuffling coefficients from one representation to another is achieved by the getarrvec function.

### Value

An object of class wd containing exactly the same information as the input object but ordered differently as a packet-ordered object.

### RELEASE

Version 3.6 Copyright Guy Nason 1997
Examples

# Generate a sequence of 32 random normals (say) and take their
# \code{packed-ordered non-decimated wavelet transform}
#
# myrand <- wst(rnorm(32))
#
# Print out the result (to verify the class and type of the object)
#
# myrand

#Class 'wst' : Stationary Wavelet Transform Object:
#    ---- : List with 8 components with names
#           wp Carray nlevelsWT filter date
#
#$WP and $Carray are the coefficient matrices

#
#Created on : Tue Sep 29 12:29:45 1998
#
#summary(.):
#----------
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
#Boundary handling: periodic

#Date: Tue Sep 29 12:29:45 1998
#
# Yep, the myrand object is of class: \code{\link{wst.object}}.
#
# Now let's convert it to class \code{\link{wd}}. The object
# gets returned and, as usual in S, is printed.
# convert(myrand)

#Class 'wd' : Discrete Wavelet Transform Object:
#    -- : List with 8 components with names
#           C D nlevelsWT fl.dbase filter type bc date
#
#$ C and $ D are LONG coefficient vectors!
#
#Created on : Tue Sep 29 12:29:45 1998
#Type of decomposition: station
#
#summary(.):
ConvertMessage

#----------
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
#Boundary handling: periodic
#Transform type: station
#Date: Tue Sep 29 12:29:45 1998
#
# The returned object is of class \code{\link{wd}} with a
type of "station".
# I.e. it has been converted successfully.

ConvertMessage

Print out a text message about an object which is from old version of WaveThresh

Description

Print out text message about an object being from an old version of WaveThresh.

Usage

ConvertMessage()

Arguments

None

Details

Description says all!

Value

None

Author(s)

G P Nason

See Also

\code{IsEarly.default}, \code{IsEarly}
Crsswav

Wrapper to C code version of rsswav

Description

Crsswav is called by WaveletCV which is itself called by threshold.wd to carry out its cross-validation policy.

Usage

Crsswav(noisy, value = 1, filter.number = 10, family = "DaubLeAsymm", thresh.type = "hard", ll = 3)

Arguments

noisy A vector of dyadic (power of two) length that contains the noisy data that you wish to compute the averaged RSS for.
value The specified threshold.
filter.number This selects the smoothness of wavelet that you want to perform wavelet shrinkage by cross-validation.
family specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
thresh.type this option specifies the thresholding type which can be "hard" or "soft".
ll The primary resolution that you wish to assume. No wavelet coefficients that are on coarser scales than ll will be thresholded.

Details

Description says all

Value

Same value as for rsswav

Author(s)

G P Nason

See Also

rsswav, WaveletCV
Estimate real signal using complex-valued wavelets

Description

Implements the multiwavelet style and empirical Bayes shrinkage procedures described in Barber & Nason (2004)

Usage

cthresh(data, j0 = 3, dwwt, dev = madmad, rule = "hard",
filter.number = 3.1, family = "LinaMayrand", plotfn = FALSE,
TI = FALSE, details = FALSE, policy = "mws", code = "NAG", tol = 0.01)

Arguments

data
The data to be analysed. This should be real-valued and of length a power of two.

j0
Primary resolution level; no thresholding is done below this level.

dwwt
description to come

dev
A function to be used to estimate the noise level of the data. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the var() function. A popular, useful and robust alternative is the madmad function.

rule
The type of thresholding done. If policy = "mws", available rules are "hard" or "soft"; if policy = "ebayes", then rule can be "hard", "soft" or "mean".

filter.number, family
These parameters specify the wavelet used. See filter.select for details.
Also, if filter.number = 5, estimation is done with all the complex-valued wavelets with 5 vanishing moments and the results averaged. If filter.number = 0, then he averaging is over all available complex-valued wavelets.

plotfn
If plotfn = true, then a plot of the noisy data and estimated signal are produced.

TI
If TI = T, then the non-decimated transform is used. See the help pages for wd and wst for more on the non-decimated transform.

details
If details = FALSE (the default), only the estimate of the underlying signal is returned. If details = TRUE, many other details are also returned.

policy
Controls the type of thresholding done. Available policies are multiwavelet style (policy = "mws") and empirical Bayes (policy = "ebayes").

code
Tells cthresh whether external C or NAG code is available to help with the calculations.

tol
A tolerance parameter used in searching for prior parameters if the empirical Bayes policy is used.
Details

If a real-valued signal is decomposed using a complex-valued wavelet (like the Lina-Mayrand wavelets supplied by filter.select), then the wavelet coefficients are also complex-valued. Wavelet shrinkage can still be used to estimate the signal, by asking the question "which coefficients are small (and represent noise) and which are large (and represent signal)?" Two methods of determining which coefficients are small and which are large are proposed by Barber & Nason (2004). One is "multiwavelet style" thresholding (similar to that in Downie & Silverman (1998) where the coefficients are treated like the coefficients of a multiwavelet). Here, the "size" of the wavelet coefficient is determined as modulus of a standardised version of the coefficient. The standardisation is by the square root of the covariance matrix of the coefficient. A Bayesian method is to place a mixture prior on each coefficient. The prior has two components: a bivariate normal and a point mass at (0,0). The parameters are determined by an empirical Bayes argument and then the prior is updated by the data.

Value

Either a vector containing the estimated signal (if details = FALSE), or a list with the following components:

- `data` The original data as supplied to cthresh.
- `data.wd` The wavelet decomposition of the data.
- `thr.wd` The thresholded version of `data.wd`.
- `estimate` The estimate of the underlying signal.
- `Sigma` The covariance matrices induced by the wavelet transform. See `make.dwwt` for more details.
- `sigsq` The estimate of the variance of the noise which corrupted the data.
- `rule` Which thresholding rule was used.
- `EBpars` The empirical Bayes parameters found by the function `find.parameters`. Only present if the "ebayes" policy was used.
- `wavelet` A list with components `filter.number` and `family` which, when supplied to `link(filter.select)`, determine the wavelet used to decompose the data.

RELEASE

Part of the CThresh addon to WaveThresh. Copyright Stuart Barber and Guy Nason 2004.

Note

The estimates returned by cthresh have an imaginary component. In practice, this component is usually negligible.

Author(s)

Stuart Barber
Cthreshold

Calls C code to threshold wd class object.

Description

A routine that calls a C code function to do thresholding. This is really a test routine to call a C thresholding function (Cthreshold) and the user is advised to use the R based generic thresholding function threshold and/or its methods as they contain a wider range of thresholding options.

Usage

Cthreshold(wd, thresh.type = "soft", value = 0, levels = 3:(nlevelsWT(wd) - 1))

Arguments

wd The wavelet object that you wish to threshold.
thresh.type The type of thresholding. This can be "soft" or "hard". See threshold and methods for further details.
value The threshold value that you want to be used (e.g. for hard thresholding wavelet coefficients whose absolute value is less than
levels The resolution levels that you wish to compute the threshold on and apply the threshold to.

Examples

# Make up some noisy data
y <- example.1()$y
ynoise <- y + rnorm(512, sd=0.1)
# Do complex-valued wavelet shrinkage with decimated wavelets
est1 <- cthresh(ynoise, TI=FALSE)
# Do complex-valued wavelet shrinkage with nondecimated wavelets
est2 <- cthresh(ynoise, TI=TRUE)

plot(1:512, y, lty=2, type="l")
lines(1:512, est1, col=2)
lines(1:512, est2, col=3)
Details

For general use it is recommended to use the `threshold` functions as they have a wider variety of options and also work for more complex varieties of wavelet transforms (i.e. non-decimated, complex-valued, etc). However, in the right, limited, situation this function can be useful. This function directly calls the C thresholding function Cthreshold(). The C function is used by routines that operate on behalf of the function that carries out two-fold cross validation in C (CWCV) which is also accessible using the policy="cv" option too `threshold.wd`

This function can be used by the user. It might be a bit faster than `threshold.wd` but mostly because it is simpler and does less checking than `threshold.wd`.

Value

A `wd.object` class object, but containing thresholded coefficients.

Author(s)

G P Nason

See Also

`threshold`  

Examples

```r
# # See copious examples in the help to threshold.wd
#```

---

CWaveDE

Simple wavelet density estimator with hard thresholding

Description


Usage

```r
CWaveDE(x, Jmax, threshold=0, nout=100, primary.resolution=1, filter.number=10, family="DaubLeAsymm", verbose=0, SF=NULL, WV=NULL)
```
Arguments

x Vector of real numbers. This is the data for which you want a density estimate for.
Jmax The maximum resolution of wavelets
threshold The hard threshold value for the wavelet coefficients
nout The number of ordinates in the density estimate
primary.resolution The usual wavelet density estimator primary resolution
filter.number The wavelet filter number, see filter.select
family The wavelet family, see filter.select
verbose The level of reporting performed by the function, legit values are 0, 1 or 2, with 2 being more reports
SF Scaling function values in format as returned by draw.default
WV Wavelet function values in format as returned by draw.default

Details

As the description.

Value

A list containing the following components:

x A vector of length nout that covers the range of the input data x, plus some more depending on the support of the wavelet and the primary resolution.
y A vector of length nout that contains the output wavelet density estimate
sfix The integer values of the translates of the scaling functions used in the estimate
wvixmin As for sfix, but a vector of length Jmax which contains the minimum integer wavelet translates
wvixmax As for wvixmin, but with the maxima

Author(s)

G P Nason

Examples

# Let's generate a bi-modal artificial set of data.
#
x <- c(rnorm(100), rnorm(100, 10))
#
# Now perform simple wavelet density estimate
#wde <- CWavDE(x, Jmax=10, threshold=1)

# Plot results
#
## Not run: plot(wde$x, wde$y, type="l")

## C Wavelet Cross-validation

### Description

Two-fold wavelet shrinkage cross-validation (in C)

### Usage

```r
CWCV(ynoise, ll, x = 1:length(ynoise), filter.number = 10, family = "DaubLeAsymm", thresh.type = "soft", tol = 0.01, 
maxits=500, verbose = 0, 
plot.it = TRUE, interptype = "noise")
```

### Arguments

- `ynoise`: A vector of dyadic (power of two) length that contains the noisy data that you wish to apply wavelet shrinkage by cross-validation to.
- `ll`: The primary resolution that you wish to assume. No wavelet coefficients that are on coarser scales than ll will be thresholded.
- `x`: This function is capable of producing informative plots. It can be useful to supply the x values corresponding to the ynoise values. Further this argument is returned by this function which can be useful for later processors.
- `filter.number`: This selects the smoothness of wavelet that you want to perform wavelet shrinkage by cross-validation.
- `family`: specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
- `thresh.type`: this option specifies the thresholding type which can be "hard" or "soft".
- `tol`: this specifies the convergence tolerance for the cross-validation optimization routine (a golden section search).
- `maxits`: maximum number of iterations for the cross-validation optimization routine (a golden section search).
- `verbose`: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default
- `plot.it`: If this is TRUE then plots of the universal threshold (used to obtain an upper bound on the cross-validation threshold) reconstruction and the resulting cross-validation estimate are produced.
- `interptype`: Can take two values noise or normal. This option controls how cross-validation compares the estimate formed by leaving out the data with the "left-out" data. If interptype="noise" then two noisy values are averaged to compare with the estimated curve in between, otherwise if interptype="normal" then the curve estimate is averaged either side of a noisy left-out point.
Details

Compute the two-fold cross-validated wavelet shrunk estimate given the noisy data ynoise according to the description given in Nason, 1996.

You must specify a primary resolution given by $ll$. This must be specified individually on each data set and can itself be estimated using cross-validation (although I haven’t written the code to do this).

Note. The two-fold cross-validation method performs very badly if the input data is correlated. In this case I would advise using the methods proposed in Donoho and Johnstone, 1995 or Johnstone and Silverman, 1997 which can be carried out in WaveThresh using the \texttt{threshold} function using the policy=\texttt{"sure"} option.

Value

A list with the following components

- \texttt{x} This is just the \texttt{x} that was input. It gets passed through more or less for convenience for the user.
- \texttt{ynoise} A copy of the input \texttt{ynoise} noisy data.
- \texttt{xvwr} The cross-validated wavelet shrunk estimate.
- \texttt{yuvtwr} The universal thresholded version (note this is merely a starting point for the cross-validation algorithm. It should not be taken seriously as an estimate. In particular its estimate of variance is likely to be inflated.)
- \texttt{xvthresh} The cross-validated threshold
- \texttt{xvdof} The number of non-zero coefficients in the cross-validated shrunk wavelet object (which is not returned).
- \texttt{uvdof} The number of non-zero coefficients in the universal threshold shrunk wavelet object (which also is not returned)
- \texttt{xkeep} always returns NULL!
- \texttt{fkeep} always returns NULL!

RELEASE

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Note

Plots of the universal and cross-validated shrunk estimates might be plotted if \texttt{plot.it=TRUE}.

Author(s)

G P Nason

See Also

\texttt{threshold}, \texttt{threshold.wd}. 
**Examples**

```
# This function is best used via the policy="cv" option in
# the threshold.wd function.
# See examples there.
```

---

**dclaw**  
*Claw distribution*

**Description**

Random generation, density and cumulative probability for the claw distribution.

**Usage**

```
rclaw(n)
dclaw(x)
pclaw(q)
```

**Arguments**

- **n**: Number of draws from `rclaw` distribution
- **x**: Vector of ordinates
- **q**: Vector of quantiles

**Details**


**Value**

Random samples (rclaw), density (dclaw) or probability (pclaw) of the claw distribution.

**Author(s)**

David Herrick

**Examples**

```r
# Plot the claw density on the interval [-3,3]
x <- seq(from=-3, to=3, length=500)
## Not run: plot(x, dclaw(x), type="l")
```
dencvwd

*Calculate variances of wavelet coefficients of a p.d.f.*

**Description**

Calculates the variances of the empirical wavelet coefficients by performing a 2D wavelet decomposition on the covariance matrix of the empirical scaling function coefficients of the probability density function.

**Usage**

```r
dencvwd(hrproj, filter.number=hrproj$filter$filter.number,
         family=hrproj$filter$family, type="wavelet", bc="zero",
         firstk=hrproj$klim, RetFather=TRUE, verbose=FALSE)
```

**Arguments**

- `hrproj`: Output from `denproj` with `covar=T` argument.
- `filter.number`: The filter number of the wavelet basis to be used. This argument should not be altered from the default, as it is tied to the `hrproj` argument.
- `family`: The family of wavelets to use. This argument should not be altered.
- `type`: The type of decomposition to be performed. This argument should not be altered.
- `bc`: The type of boundary conditions to be used. For density estimation this should always be zero.
- `firstk`: The bounds on the translation index of the empirical scaling function coefficients.
- `RetFather`: Ignore this.
- `verbose`: If TRUE the function will be chatty. Note that comments are only available for part of the algorithm, so might not be very enlightening.

**Details**

This function is basically `imwd` adapted to handle zero boundary conditions, except that only the variances are returned, i.e., the diagonals of the covariance matrices produced. Note that this code is not very efficient. The full covariance matrices of all levels of coefficients are calculated, and then the diagonals are extracted.

**Value**

An object of class `wd.object`, but the contents are not a standard wavelet transform, i.e., the object is used to hold other information which organisationally is arranged like a wavelet transform, i.e., variances of coefficients.
**denplot**

*Author(s)*

David Herrick

**See Also**

denproj, imwd

**Examples**

```r
# Simulate data from the claw density, find the
# empirical scaling function coefficients and covariances and then decompose
# both to give wavelet coefficients and their variances.

data <- rclaw(100)
datahr <- denproj(data, J=8, filter.number=2, family="DaubExPhase", covar=TRUE)
data.wd <- denwd(datahr)
## Not run: plotdenwd(data.wd, top.level=(datahr$res$J-1))

datavar <- dencvwd(datahr)
## Not run: plotdenwd(datavar, top.level=(datahr$res$J-1))
```

---

**denplot**  
*Calculate plotting information for a density estimate.*

**Description**

Calculates plotting information for a wavelet density estimate from high level scaling function coefficients.

**Usage**

denplot(wr, coef, nT=20, lims, n=50)

**Arguments**

- `wr`: Scaling function coefficients, usually at some high level and usually smoothed (thresholded).
- `coef`: The output from `denproj` for this analysis, i.e. the object containing the empirical scaling function coefficients. This is required because of the information it contains about the wavelet filter used, the resolution of the projection, and the bounds on the translation index of the scaling function coefficients.
- `lims`: Vector containing the minimum and maximum x values required on the plot.
- `nT`: The number of iterations to be performed in the Daubechies-Lagarias algorithm, which is used to evaluate the scaling functions of the specified wavelet basis at the plotting points.
- `n`: The number of points at which the density estimate is to be evaluated.
Details

The density estimate is evaluated at \( n \) points between the values in \( \text{lims} \). This function can be used to plot the empirical scaling function density estimate by entering \( \text{wr} = \text{coef} \times \text{coef} \), but since the empirical coefficients are usually found at some very high resolution, such a plot will be very noisy and not very informative. This function will be of much more use as and when thresholding function are included in this density estimation package.

Value

A list with components:

- \( x \) The points at which the density estimate is evaluated.
- \( y \) The values of the density estimate at the points in \( x \).

Author(s)

David Herrick

See Also

denproj, rclaw

Examples

```r
# Simulate data from the claw density and find the
# empirical scaling function coefficients at a lowish resolution and plot
# the resulting density estimate
data <- rclaw(100)
datahr <- denproj(data, J=3, filter.number=2, family="DaubExPhase")
datapl <- denplot(datahr$coef, datahr, lims=c(-3,3), n=1000)
## Not run: plot(datapl, type="l")
```

---

**Description**

Calculates empirical scaling function coefficients of the probability density function from sample of data from that density, usually at some "high" resolution.

**Usage**

```
denproj(x, tau=1, J, filter.number=10, family="DaubLeAsymm", covar=FALSE, nT=20)
```
Arguments

x  Vector containing the data. This can be of any length.
J  The resolution level at which the empirical scaling function coefficients are to be calculated.
tau This parameter allows non-dyadic resolutions to be used, since the resolution is specified as tau * 2^J.
filter.number The filter number of the wavelet basis to be used.
family The family of wavelets to use, can be "DaubExPhase" or "DaubLeAsymm".
covar Logical variable. If TRUE then covariances of the empirical scaling function coefficients are also calculated.
nT The number of iterations to be performed in the Daubechies-Lagarias algorithm, which is used to evaluate the scaling functions of the specified wavelet basis at the data points.

Details

This projection of data onto a high resolution wavelet space is described in detail in Chapter 3 of Herrick (2000). The maximum and minimum values of k for which the empirical scaling function coefficient is non-zero are determined and the coefficients calculated for all k between these limits as \( \text{sum}(\phi_J k(x_i))/n \). The scaling functions are evaluated at the data points efficiently, using the Daubechies-Lagarias algorithm (Daubechies & Lagarias (1992)). Coded kindly by Brani Vidakovic.


Value

A list with components:

coef A vector containing the empirical scaling function coefficients. This starts with the first non-zero coefficient, ends with the last non-zero coefficient and contains all coefficients, including zeros, in between.
covar Matrix containing the covariances, if requested.
klim The maximum and minimum values of k for which the empirical scaling function coefficients cJk are non-zero.
p The primary resolution \( \text{tau} \times 2^J \).
filter A list containing the filter.number and family specified in the function call.
n The length of the data vector x.
res A list containing the values of p, tau and J.

Author(s)

David Herrick
See Also

Chires5, Chires6, denwd, denwr

Examples

# Simulate data from the claw density and find the
# empirical scaling function coefficients
data <- rclaw(100)
datahr <- denproj(data, J=8, filter.number=4,family="DaubLeAsymm")

denwd

Wavelet decomposition of empirical scaling function coefficients of a p.d.f.

Description

Performs wavelet decomposition on the empirical scaling function coefficients of the probability density function.

Usage

denwd(coef)

Arguments

coef Output from denproj

Details

The empirical scaling function coefficients are decomposed using the DWT with zero boundary conditions.

Value

An object of class wd.object

Author(s)

David Herrick

See Also

denproj, plotdenwd, wd, denwr
Examples

```r
# Simulate data from the claw density, find the empirical
# scaling function coefficients, decompose them and plot
# the resulting wavelet coefficients

data <- rclaw(100)
datahr <- denproj(data, J=8, filter.number=2, family="DaubExPhase")
data.wd <- denwd(datahr)
## Not run: plotdenwd(data.wd, top.level=(datahr$res$J-1))
```

---

**denwr**

Wavelet reconstruction for density estimation.

**Description**

Performs wavelet reconstruction for density estimation.

**Usage**

```r
denwr(wd, start.level=0, verbose=FALSE, bc=wd$bc,
      return.object=FALSE, filter.number=wd$filter$filter.number,
      family=wd$filter$family)
```

**Arguments**

- `wd`: Wavelet decomposition object to reconstruct
- `start.level`: The level you wish to start the reconstruction at. This is usually the first level (level 0). Note that this option assumes the coarsest level is labelled 0, so it is best to think of this argument as "the number of levels up from the coarsest level to start the reconstruction".
- `verbose`: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
- `bc`: The boundary conditions used. These should be determined by those used to create the supplied `wd.object` object. In the case of density estimation they are "zero".
- `filter.number`: The filter number of the wavelet used to do the reconstruction. Again, as for `bc`, you should probably leave this argument alone.
- `family`: The type of wavelet used to do the reconstruction. You can change this argument from the default but it is probably NOT wise.
- `return.object`: If this is `FALSE` then the top level of the reconstruction is returned (this is the reconstructed function at the highest resolution). Otherwise, if it is `TRUE`, the whole `wd` reconstructed object is returned.

**Details**

This is the same as `wr.wd`, except that it can handle zero boundary conditions.
Value

Either a vector containing the top level reconstruction or an object of class \texttt{wd.object} containing the results of the reconstruction.

Author(s)

David Herrick

---

**DJ.EX**

*Produce Donoho and Johnstone test functions*

Description

Function to produce the blocks, bumps, Doppler and heavisine functions described by Donoho and Johnstone (1994).

Usage

\[
\text{DJ.EX}(n = 1024, \text{signal} = 7, \text{rsnr} = 7, \text{noisy} = \text{FALSE}, \text{plotfn} = \text{FALSE})
\]

Arguments

- **n**: Number of samples of the function required.
- **signal**: A factor that multiplies the function values.
- **rsnr**: If Gaussian noise is to be added to the functions then this argument specifies the root signal to noise ratio.
- **noisy**: If TRUE then Gaussian noise is added to the signal so that the root signal to noise ratio is \( \text{rsnr} \). If FALSE then just the signals are returned.
- **plotfn**: If TRUE then a plot is produced. If FALSE no plot is produced.

Details

The Donoho and Johnstone test functions were designed to reproduce various features to be found in real world signals such as jump discontinuities (blocks), spikes (the NMR-like bumps), varying frequency behaviour (Doppler) and jumps/spikes in smooth signals (heavisine). These functions are most often used for testing wavelet shrinkage methods and comparing them to other nonparametric regression techniques. (Donoho, D.L. and Johnstone, I.M. (1994), Ideal spatial adaptation by wavelet shrinkage. *Biometrika*, **81**, 425–455).

Another version of the Doppler function can be found in the standalone \texttt{doppler} function.


\textit{NOTE: This function might not give exactly the same function values as the equivalent function in WaveLab}
Value
A list with four components: blocks, bumps, heavi and doppler containing the sampled signal values for the four types of Donoho and Johnstone test functions. Each of these are deemed to be sampled on an equally spaced grid from 0 to 1.

Author(s)
Theofanis Sapatinas

See Also
doppler.example.1, threshold, wd

Examples

```r
# Show a picture of the four test functions with the default args
#
## Not run: DJ.EX(plotfn=TRUE)
```

```r
dof
```

Compute number of non-zero coefficients in wd object

Description
Compute number of non-zero coefficients in wd object

Usage
dof(wd)

Arguments

wd A wavelet decomposition object (such as that returned by the wd function).

Details
Very simple function that counts the number of non-zero coefficients in a wd class object.

Value
An integer that represents the number of non-zero coefficients in the input wd object.

RELEASE
Version 3.0 Copyright Guy Nason 1994
Evaluate the Donoho and Johnstone Doppler signal.

This function evaluates and returns the Doppler signal from Donoho and Johnstone, (1994).

doppler(t)
Arguments

- `t` The domain of the Doppler function (where you wish to evaluate this Doppler function)

Details


Another version of this function can be found in `DJ.EX`.

Value

A vector of the same length as the input vector containing the Doppler signal at `t`.

Author(s)

Arne Kovac

See Also

- `DJ.EX`

Examples

```r
# Evaluate the Doppler signal at 100 arbitrarily spaced points.

tt <- sort(runif(100))
dopp <- doppler(tt)
## Not run: plot(tt, dopp, type="l")
```

Description

Draws the mother wavelet or scaling function associated with an object.

This function is generic. Particular methods exist. The following functions are used for the following objects:

- `imwd.object` the `draw.imwd` function is used.
- `imwdc.object` the `draw.imwdc` function is used.
- `wd.object` the `draw.wd` function is used.
- `wp.object` the `draw.wp` function is used.
- `wst.object` the `draw.wst` function is used.

All of the above method functions use the `draw.default` function which is the function which actually does the drawing.
draw.default

Usage

draw(...)

Arguments

... methods may have additional arguments

Details

See individual method help pages for operation and examples.

Value

If the plot.it argument is supplied then the draw functions tend to return the coordinates of what they were meant to draw and don’t actually draw anything.

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Author(s)

G P Nason

See Also

draw.default, draw.imwd, draw.imwdc, draw.wd, draw.wp, draw.wst, imwd.object, imwdc.object, wd.object, wp.object, wst.object.

draw.default

Draw picture of a wavelet or scaling function.

Description

This function can produce pictures of one- or two-dimensional wavelets or scaling functions at various levels of resolution.

Usage

## Default S3 method:

# Default S3 method:
draw(filter.number = 10, family = "DaubLeAsymm", resolution = 8192,
   verbose = FALSE, plot.it = TRUE, main = "Wavelet Picture", sub = zwd$
   filter$name, xlab = "x", ylab = "psi", dimension = 1, twodplot
   = persp, enhance = TRUE, efactor = 0.05, scaling.function = FALSE,
   type="l",
   ...)}
Arguments

filter.number  This selects the index number of the wavelet or scaling function you want to
draw (from within the wavelet family).

family  specifies the family of wavelets that you want to draw. The options are "DaubEx-
Phase" and "DaubLeAsymm".

resolution  specifies the resolution that the wavelet or scaling function is computed to. It
does not necessarily mean that you see all of these points as if the enhance option
is TRUE then some function points are omitted.

verbose  Controls the printing of "informative" messages whilst the computations progress.
Such messages are generally annoying so it is turned off by default.

plot.it  If TRUE then this function attempts to plot the function (i.e. draw it on a graphics
device which should be active). If FALSE then this function returns the
coordinates of the object that would have been plotted.

main  a main title for the plot

sub  a subtitle for the plot.

xlab  a label string for the x-axis

ylab  a label string for the y-axis

dimension  whether to make a picture of the one-dimensional wavelet or the two-dimensional
wavelet.

twodplot  which function to use to produce the two-dimensional plot if dimension=2. The
function you supply should accept data just like the contour or persp functions
supplied with S-Plus.

enhance  If this argument is TRUE then the plot is enhanced in the following way. Many
of Daubechies’ compactly supported wavelets are near to zero on a reasonable
proportion of their support. So if such a wavelet is plotted quite a lot of it looks to
be near zero and the interesting detail seems quite small. This function chooses
a nice range on which to plot the central parts of the function and the function is
plotted on this range.

efactor  Variable which controls the range of plotting associated with the enhance option
above. Any observations smaller than efactor times the range of the absolute
function values are deemed to be too small. Then the largest range of “non-
small” values is selected to be plotted.

scaling.function  If this argument is TRUE the scaling function is plotted otherwise the mother
wavelet is plotted.

type  The type argument supplied to the plot command

...  other arguments you can supply to the plot routine embedded within this func-
tion.

Details

The algorithm underlying this function produces a picture of the wavelet or scaling function by
first building a wavelet decomposition object of the correct size (i.e. correct resolution) and
setting all entries equal to zero. Then one coefficient at a carefully selected resolution level is set to
one and the decomposition is inverted to obtain a picture of the wavelet.
Value

If `plot.it=FALSE` then usually a list containing coordinates of the object that would have been plotted is returned. This can be useful if you don’t want S-Plus to do the plotting or you wish to use the coordinates of the wavelets for other purposes.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Note

A plot is produced of the wavelet or scaling function if `plot.it=TRUE`.

Author(s)

G P Nason

See Also

`filter.select`, `ScalingFunction`, `wd`, `wd.object`, `wr`, `wr.wd`.

Examples

```r
# First make sure that your favourite graphics device is open
# otherwise S-Plus will complain.
#
# Let's draw a one-dimensional Daubechies least-asymmetric wavelet
# N=10
#
## Not run: draw.default(filter.number=10, family="DaubLeAsymm")
#
# Wow. What a great picture!
#
# Now how about a one-dimensional Daubechies extremal-phase scaling function
# with N=2
#
## Not run: draw.default(filter.number=2, family="DaubExPhase")
#
# Excellent! Now how about a two-dimensional Daubechies least-asymmetric
# N=6 wavelet
#
# N.b. we'll also reduce the resolution down a bit. If we used the default
# resolution of 8192 this would be probably too much for most computers.
#
## Not run: draw.default(filter.number=6, family="DaubLeAsymm", dimension=2, res=256)
#
# What a pretty picture!
```
**draw.imwd**

Draw mother wavelet associated with an imwd object.

### Description

This function draws the mother wavelet associated with an `imwd.object` — a two-dimensional wavelet decomposition.

### Usage

```r
## S3 method for class 'imwd'
draw(wd, resolution=128, ...)
```

### Arguments

- **wd**: The `imwd` class object whose associated wavelet you wish to draw.
- **resolution**: The resolution at which the computation is done to compute the wavelet picture. Generally the resolution should be lower for two-dimensional wavelets since the number of computations is proportional to the square of the resolution (the DWT is still O(n) though).
- **...**: Additional arguments to pass to the `draw.default` function which does the drawing.

### Details

This function extracts the `filter` component from the `imwd` object (which is constructed using the `filter.select` function) to decide which wavelet to draw. Once decided the `draw.default` function is used to actually do the drawing.

### Value

If the `plot.it` argument is set to `TRUE` then nothing is returned. Otherwise, as with `draw.default`, the coordinates of what would have been plotted are returned.

### RELEASE

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### Note

If the `plot.it` argument is `TRUE` (which it is by default) a plot of the mother wavelet or scaling function is plotted on the active graphics device.

### Author(s)

G P Nason
See Also

filter.select.imwd.object, draw.default.

Examples

# Let's use the lennon test image
# data(lennon)
## Not run: image(lennon)
# Now let's do the 2D discrete wavelet transform using Daubechies'
# least-asymmetric wavelet N=6
# lwd <- imwd(lennon, filter.number=6)
# And now draw the wavelet that did this transform
# ## Not run: draw(lwd)
# # A nice little two-dimensional wavelet!
#

draw.imwdc

Draw mother wavelet associated with an imwdc object.

Description

This function draws the mother wavelet associated with an imwdc.object — a compressed two-dimensional wavelet decomposition.

Usage

## S3 method for class 'imwdc'
draw(wd, resolution=128, ...)

Arguments

wd The imwd class object whose associated wavelet you wish to draw. (I know its called wd, sorry).
resolution The resolution at which the computation is done to compute the wavelet picture. Generally the resolution should be lower for two-dimensional wavelets since the number of computations is proportional to the square of the resolution (the DWT is still O(n) though).
... Additional arguments to pass to the draw.default function which does the drawing.
**draw.imwdc**

**Details**
This function extracts the filter component from the `imwd` object (which is constructed using the `filter.select` function) to decide which wavelet to draw. Once decided the `draw.default` function is used to actually do the drawing.

**Value**
If the `plot.it` argument is set to `TRUE` then nothing is returned. Otherwise, as with `draw.default`, the coordinates of what would have been plotted are returned.

**RELEASE**
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**Note**
If the `plot.it` argument is `TRUE` (which it is by default) a plot of the mother wavelet or scaling function is plotted on the active graphics device.

**Author(s)**
G P Nason

**See Also**
`filter.select`, `imwdc.object`, `draw.default`.

**Examples**
```r
# Let's use the lennon test image
# data(lennon)
## Not run: image(lennon)
#
# Now let's do the 2D discrete wavelet transform using Daubechies'
# least-asymmetric wavelet N=6
#
# lwd <- imwd(lennon, filter.number=6)
#
# Now let's threshold the 2D DWT
# The resultant class of object is imwdc object.
#
# lwdT <- threshold(lwd)
#
# And now draw the wavelet that did this transform
#
## Not run: draw(lwdT)
#
# A nice little two-dimensional wavelet!
```
draw.mwd

**Draws a wavelet or scaling function used to compute an 'mwd' object**

**Description**

Draws picture of one wavelet or scaling function associated with the multiple wavelet decomposition object. `mwd.object`.

**Usage**

```r
## S3 method for class 'mwd'
draw(mwd, phi = 0, psi = 0, return.funct = FALSE, ...)
```

**Arguments**

- `mwd`: The `mwd` class object whose associated wavelet or scaling function you wish to draw.
- `phi`: description not yet available
- `psi`: If `phi` is non-zero then the 'phi'-th scaling function of the wavelet family used for `mwd` will be plotted. `phi` must be between 0 and `mwd$filter$nphi`.
- `return.funct`: If true then the vector used as `phi/psi` in the plot command is returned.
- `...`: Additional arguments to pass to the `plot` function

**Details**

It is usual to specify just one of `phi` and `psi`. IF neither `phi` nor `psi` are specified then `phi=1` is the default. An error is generated if both `phi=0` and `psi=0` or if both are nonzero.

**Value**

If the `return.funct` argument is set to `TRUE` then the function values in the plot are returned otherwise `NULL` is returned.

**RELEASE**

Version 3.9.6 (Although Copyright Tim Downie 1995-6).

**Note**

If the `return.funct` argument is `FALSE` a plot of the mother wavelet or scaling function is plotted on the active graphics device.

**Author(s)**

G P Nason
See Also

accessC.mwd, accessD.mwd, mfirst.last, mfilter.select, mwd, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

```r
# Do a multiple wavelet decomposition on vector: ynoise
#
ynoise <- rnorm(512, sd = 0.1)
ymwd <- mwd(ynoise, filter.type="Geronimo")
#
# Draw a picture of the second Geronimo wavelet.
#
## Not run: draw(ymwd, psi=2)
```

```
draw.wd

Draw mother wavelet or scaling function associated with wd object.

Description

This function draws the mother wavelet or scaling function associated with a wd.object.

Usage

```r
## S3 method for class 'Var' wd
draw(wd, ...)```

Arguments

- `wd` The wd class object whose associated wavelet or scaling function you wish to draw.
- `...` Additional arguments to pass to the draw.default function which does the drawing. In particular, arguments can be set to choose between drawing the mother wavelet and scaling function, to set the resolution of the plot, to choose between drawing one and two dimensional pictures.

Details

This function extracts the filter component from the wd object (which is constructed using the filter.select function) to decide which wavelet to draw. Once decided the draw.default function is used to actually do the drawing.

Value

If the plot.it argument is set to TRUE then nothing is returned. Otherwise, as with draw.default, the coordinates of what would have been plotted are returned.
Note

If the plot.it argument is TRUE (which it is by default) a plot of the mother wavelet or scaling function is plotted on the active graphics device.

Author(s)

G P Nason

See Also

filter.select, wd.object, draw.default.

Examples

# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Now do the discrete wavelet transform of the data using the Daubechies
# least-asymmetric wavelet N=10 (the default arguments in
# wd).
#
tdwd <- wd(test.data)
#
# What happens if we try to draw this new tdwd object?
#
## Not run: draw(tdwd)
#
# We get a picture of the wavelet that did the transform
#

draw/wp

Draw wavelet packet associated with a wp object.

Description

This function draws a wavelet packet associated with a wp.object.

Usage

## S3 method for class 'wp'
draw(wp, level, index, plot.it=TRUE, main, sub, xlab, ylab, ...)

release

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Arguments

- **wp**: The `wp` class object whose associated wavelet packet you wish to draw.
- **level**: The resolution level of wavelet packet in the wavelet packet decomposition that you wish to draw (corresponds to scale).
- **index**: The packet index of the wavelet packet in the wavelet packet decomposition that you wish to draw (corresponds to number of oscillations).
- **plot.it**: If TRUE then the wavelet packet is plotted on the active graphics device. If FALSE then the y-coordinates of the packet are returned. Note that x-coordinates are not returned (the packet is periodic on its range anyway).
- **main**: The main argument for the plot
- **sub**: The subtitle for the plot
- **xlab**: The labels for the x axis
- **ylab**: The labels for the y axis
- **...**: Additional arguments to pass to the `drawwp.default` function which does the drawing. In particular, arguments can be set to choose between drawing the mother wavelet and scaling function, to set the resolution of the plot, to choose between drawing one and two dimensional pictures.

Details

This function extracts the filter component from the `wp` object (which is constructed using the `filter.select` function) to decide which wavelet packet family to draw. Once decided the `drawwp.default` function is used to actually do the drawing.

Value

If the `plot.it` argument is set to TRUE then nothing is returned. Otherwise, if `plot.it` is set to FALSE the coordinates of what would have been plotted are returned.

RELEASE

Version 3.9.6 Copyright Guy Nason 1998

Note

If the `plot.it` argument is TRUE (which it is by default) a plot of the appropriate wavelet packet is plotted on the active graphics device.

Author(s)

G P Nason

See Also

`filter.select`, `wp`, `wp.object`, `drawwp.default`
Examples

```
# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Now do the wavelet packet transform of the data using the Daubechies
# least-asymmetric wavelet N=10 (the default arguments in
# wp).
#
tdwp <- wp(test.data)
#
# What happens if we try to draw this new tdwp object?
#
## Not run: draw(tdwp, level=4, index=12)
```

draw.wst

Draw mother wavelet or scaling function associated with wst object.

Description

This function draws the mother wavelet or scaling function associated with a wst.object.

Usage

```
## S3 method for class 'wst'
draw(wst, ...)
```

Arguments

- `wst` The wst class object whose associated wavelet or scaling function you wish to draw.
- `...` Additional arguments to pass to the draw.default function which does the drawing. In particular, arguments can be set to choose between drawing the mother wavelet and scaling function, to set the resolution of the plot, to choose between drawing one and two dimensional pictures.

Details

This function extracts the filter component from the wst object (which is constructed using the filter.select function) to decide which wavelet packet family to draw. Once decided the draw.default function is used to actually do the drawing.

Value

If the plot.it argument is set to TRUE then nothing is returned. Otherwise, as with draw.default, the coordinates of what would have been plotted are returned.
Note

If the plot.it argument is TRUE (which it is by default) a plot of the appropriate wavelet packet is plotted on the active graphics device.

Author(s)

G P Nason

See Also

filter.select, wst.object, draw.default.

Examples

# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Now do the \code{packet-ordered non-decimated DWT} of the data using the Daubechies
# least-asymmetric wavelet N=10 (the default arguments in \code{\link{wst}}).
#
tdwst <- wst(test.data)
#
# What happens if we try to draw this new tdwst object?
#
## Not run: draw(tdwst)
#
# We get a picture of the wavelet that did the transform
#

---

drawbox

**Draw a shaded coloured box**

**Description**

Simply draws a box with bottom left corner at (x,y), or width w and height h with shading of density and colour of col.

**Usage**

drawbox(x,y,w,h,density,col)
**Arguments**

- **x**  
  The bottom left x coordinate of the box  
- **y**  
  The bottom left y coordinate of the box  
- **w**  
  The width of the box  
- **h**  
  The height of the box  
- **density**  
  The shading density of the box  
- **col**  
  The colour of the box

**Details**

Description says all

**Value**

None

**Author(s)**

G P Nason

**See Also**

addpkt

---

**Description**

Function computes the values of a given wavelet packet on a discrete grid.

**Usage**

```r
drawwp.default(level, index, filter.number = 10, family = "DaubLeAsymm", resolution = 64 * 2^level)
```

**Arguments**

- **level**  
  The resolution level of the packet you want  
- **index**  
  The packet index of the packet you want  
- **filter.number**  
  The type of wavelet you want, see `filter.select`  
- **family**  
  The family of wavelet you want, see `filter.select`  
- **resolution**  
  The number of ordinates at which you want the wavelet packet
ewspec

Details

Function works by computing a wavelet packet transform of a zero vector. Then inserting a single one somewhere in the desired packet, and then inverts the transform.

Value

A vector containing the "y" values of the required wavelet packet.

Author(s)

G P Nason

See Also

draw.wp, InvBasis, nlevelsWT, putpacket, wp

Description

This function computes the evolutionary wavelet spectrum (EWS) estimate from a time series (or non-decimated wavelet transform of a time series). The estimate is computed by taking the non-decimated wavelet transform of the time series data, taking its modulus; smoothing using TI-wavelet shrinkage and then correction for the redundancy caused by use of the non-decimated wavelet transform. Options below beginning with smooth. are passed directly to the TI-wavelet shrinkage routines.

Usage

ewspec(x, filter.number = 10, family = "DaubLeAsymm", UseLocalSpec = TRUE, DoSWT = TRUE, WPsmooth = TRUE, verbose = FALSE, smooth.filter.number = 10, smooth.family = "DaubLeAsymm", smooth.levels = 3:(nlevelsWT(WPwst) - 1), smooth.dev = madmad, smooth.policy = "LSuniversal", smooth.value = 0, smooth.by.level = FALSE, smooth.type = "soft", smooth.verbose = FALSE, smooth.cvtol = 0.01, smooth.cvnorm = l2norm, smooth.transform = I, smooth.inverse = I)

Arguments

x The time series that you want to analyze. (See DETAILS below on how to supply preprocessed versions of the time series which bypass early parts of the ewspec function).
filter.number  This selects the index of the wavelet used in the analysis of the time series (i.e.,
the wavelet basis functions used to model the time series). For Daubechies compac-

tly supported wavelets the filter number is the number of vanishing moments.

family  This selects the wavelet family to use in the analysis of the time series (i.e.,
which wavelet family to use to model the time series). Only use the Daubechies compac-

tly supported wavelets DaubExPhase and DaubLeAsymm.

UseLocalSpec  If you input a time series for x then this argument should always be T. (How-
ever, you can precompute the modulus of the non-decimated wavelet transform
yourself and supply it as x in which case the LocalSpec call within this function
is not necessary and you can set UseLocalSpec equal to F).

DoSWT  If you input a time series for x then this argument should always be T. (However,
you can precompute the non-decimated wavelet transform yourself and supply
it as x in which case the wd call within the function will not be necessary and
you can set DoSWT equal to F).

WPsmooth  Normally a wavelet periodogram is smoothed before it is corrected. Use WPsmooth=F
is you do not want any wavelet periodogram smoothing (correction is still done).

verbose  If this option is T then informative messages are printed as the function pro-
gresses.

smooth.filter.number  This selects the index number of the wavelet that smooths each scale of the
wavelet periodogram. See filter.select for further details on which wavelets
you can use. Generally speaking it is a good idea to use a smoother wavelet for
smoothing than the one you used for analysis (above) but since one still wants
local smoothing it is best not to use a wavelet that is much smoother.

smooth.family  This selects the wavelet family that smooths each scale of the wavelet peri-
odogram. See filter.select for further details on which wavelets you can
use. There is no need to use the same family as you used to analyse the time
series.

smooth.levels  The levels to smooth when performing the TI-wavelet shrinkage smoothing.

smooth.dev  The method for estimating the variance of the empirical wavelet coefficients for
smoothing purposes.

smooth.policy  The recipe for smoothing: determines how the threshold is chosen. See threshold
for TI-smoothing and choice of potential policies. For EWS estimation LSuniversal
is recommended for the Chi-squared nature of the periodogram coefficients.
However, if the coefficients are transformed (using smooth.transform and smooth.inverse)
then other, more standard, policies may be appropriate.

smooth.value  When a manual policy is being used this argument is used to supply a threshold
value. See threshold for more information.

smooth.by.level  If TRUE then the wavelet shrinkage is performed by computing and applying a
separate threshold to each level in the non-decimated wavelet transform of each
scale. Note that each scale in the EWS is smoothed separately and independ-
ently: and each smooth consists of taking the (second-stage) non-decimated
wavelet transform and applying a threshold to each level of a wavelet trans-
formed scale.
If FALSE then the same threshold is applied to the non-decimated wavelet transform of a scale. Different thresholds may be computed for different scales (in the time series model) but the threshold will be the same for each level arising from the non-decimated transform of a scale.

Note: a scale refers to a set of coefficients coming from a particular scale of the non-decimated wavelet transform of the time series data that models the time series. A level refers to the levels of wavelet coefficients obtained from taking the non-decimated wavelet transform of a particular scale.

**smooth.type**  
The type of shrinkage: either "hard" or "soft".

**smooth.verbose**  
If TRUE then informative messages concerning the TI-transform wavelet shrinkage are printed.

**smooth.cvtol**  
If cross-validated wavelet shrinkage (smooth.policy="cv") is used then this argument supplies the cross-validation tolerance.

**smooth.cvnorm**  
No description for object

**smooth.transform**  
The transform function to use to transform the wavelet periodogram estimate. The wavelet periodogram coefficients are typically chi-squared in nature, a log transform can pull the coefficients towards normality so that a smooth.policy for Gaussian data could be used (e.g. universal).

**smooth.inverse**  
The inverse transform of smooth.transform.

**Details**

This function computes an estimate of the evolutionary wavelet spectrum of a time series according to the paper by Nason, von Sachs and Kroisandt. The function works as follows:

1. The non-decimated wavelet transform of the series is computed.
2. The squared modulus of the non-decimated wavelet transform is computed (this is the raw wavelet periodogram, which is returned).
3. The squared modulus is smoothed using TI-wavelet shrinkage.
4. The smoothed coefficients are corrected using the inverse of the inner product matrix of the discrete non-decimated autocorrelation wavelets (produced using the ipndacw function).

To display the EWS use the `plot` function on the S component, see the examples below.

It is possible to supply the non-decimated wavelet transform of the time series and set DoSWT=F or to supply the squared modulus of the non-decimated wavelet transform using LocalSpec and setting UseLocalSpec=F. This facility saves time because the function is then only used for smoothing and correction.

**Value**

A list with the following components:

- **S**  
The evolutionary wavelet spectral estimate of the input x. This object is of class wd and so can be plotted, printed in the usual way.
WavPer

The raw wavelet periodogram of the input x. The EWS estimate (above) is the smoothed corrected version of the wavelet periodgram. The wavelet periodogram is of class wd and so can be plotted, printed in the usual way.

rm

This is the matrix A from the paper by Nason, von Sachs and Kroisandt. Its inverse is used to correct the raw wavelet periodogram. This matrix is computed using the ipndacw function.

irm

The inverse of the matrix A from the paper by Nason, von Sachs and Kroisandt. It is used to correct the raw wavelet periodogram.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

References


See Also

Baby Data, filter.select, ipndacw, LocalSpec, threshold wd wd.object

Examples

```
# Apply the EWS estimate function to the baby data
```

```r
example.1()
```

Description

This function computes and returns the coordinates of the piecewise polynomial described by Nason and Silverman, 1994. This function is a useful test function for evaluating wavelet shrinkage methodology as it contains smooth parts, a discontinuity and it is periodic.


Usage

```
example.1()
```
filter.select

Arguments

None

Details

This function computes and returns the x and y coordinates of the piecewise polynomial function described in Nason and Silverman, 1994. The formula for the piecewise polynomial (which is piecewise cubic) is given in Nason and Silverman, 1994.

The piecewise polynomial returned is a discrete sample on 512 equally spaced points between 0 and 1 (including 0 but excluding 1).

The Donoho and Johnstone test functions can be generated using the DJ.EX function.

Value

A list with two components:

\[
\begin{align*}
  x & \quad \text{a vector of length 512 containing the ordered x ordinates of the piecewise polynomial.} \\
  y & \quad \text{a vector of length 512 containing the corresponding y ordinates of the piecewise polynomial.}
\end{align*}
\]

Author(s)

G P Nason

See Also

DJ.EX

Examples

```r
# Generate the piecewise polynomial
#
# test.data <- example.1()$y
## Not run: ts.plot(test.data)
```

Description

This function stores the filter coefficients necessary for doing a discrete wavelet transform (and its inverse), including complex-valued compactly supported wavelets.

Usage

```r
filter.select(filter.number, family="DaubLeAsymm", constant=1)
```
Arguments

filter.number  This selects the desired filter, an integer that takes a value dependent upon the family that you select. For the complex-valued wavelets in the Lina-Mayrand family, the filter number takes the form x.y where x is the number of vanishing moments (3, 4, or 5) and y is the solution number (1 for x = 3 or 4 vanishing moments; 1, 2, 3, or 4 for x = 5 vanishing moments). Note: this argument has a different meaning for Littlewood-Paley wavelets, see the note below in the Details section.

family  This selects the basic family that the wavelet comes from. The choices are DaubExPhase for Daubechies’ extremal phase wavelets, DaubLeAsymm for Daubechies’ “least-asymmetric” wavelets, Coiflets for Coiflets, Lawton for Lawton’s complex-valued wavelets (equivalent to Lina-Mayrand 3.1 wavelets), LittlewoodPaley for a approximation to Littlewood-Paley wavelets, or LinaMayrand for the Lina-Mayrand family of complex-valued Daubechies’ wavelets.

constant  This constant is applied as a multiplier to all the coefficients. It can be a vector, and so you can adapt the filter coefficients to be whatever you want. (This is feature of negative utility, or “there is less to this than meets the eye” as my old PhD supervisor would say [GPN]).

Details

This function contains at least three types of filter. Two types can be selected with family set to DaubExPhase; these wavelets are the Haar wavelet (selected by filter.number=1 within this family) and Daubechies “extremal phase” wavelets selected by filter.numbers ranging from 2 to 10). Setting family to DaubLeAsymm gives you Daubechies least asymmetric wavelets, but here the filter number ranges from 4 to 10. For Daubechies wavelets, filter.number corresponds to the N of that paper, the wavelets become more regular as the filter.number increases, but they are all of compact support.

With family equal to “Coiflets” the function supports filter numbers ranging from 1 to 5. Coiflets are wavelets where the scaling function also has vanishing moments.

With family equal to “LinaMayrand”, the function returns complex-valued Daubechies wavelets. For odd numbers of vanishing moments, there are symmetric complex-valued wavelets in this family, and for five or more vanishing moments there are multiple distinct complex-valued wavelets, distinguished by their (arbitrary) solution number. At present, Lina-Mayrand wavelets 3.1, 4.1, 5.1, 5.2, 5.3, and 5.4 are available in WaveThresh.

Setting family equal to “Lawton” chooses complex-valued wavelets. The only wavelet available is the one with “filter.number” equal to 3.

With family equal to “LittlewoodPaley” the Littlewood-Paley wavelet is used. The scaling function is also the same as (or at least proportional to, depending on your normalization) that of the Shannon scaling function, so its an approximation to the Shannon wavelet transform. The “filter.number” argument has a special meaning for the Littlewood-Paley wavelets: it does not represent vanishing moments here. Instead, it controls the number of filter taps in the quadrature mirror filter: typically longer values are better, up to the length of the series. Increasing it higher than the length of the series does not usually have much effect. Note: extreme caution should be taken with the Littlewood-Paley wavelet. This implementation is pure time-domain and as such can only be thought of as an approximation to a complete Shannon/LP implementation. For example, in actuality the wavelets
are NOT finite impulse response filters like with Daubechies wavelets. This means that it is possible for an infinite number of Littlewood Paley wavelet coefficients to be nonzero. However, computers can not store an infinite number of coefficients and some will be lost. This is most noticeable with functions with discontinuities and other homogeneities but it can also happen with some smooth functions. A way to check how “bad” is can be is to transform your desired function followed immediately by the inverse transform and compare the original with the resultant sequence.

The function `compare.filters` can be used to compare two filters.

Value

A list is returned with four components describing the filter:

- `H`: A vector containing the filter coefficients.
- `G`: A vector containing filter coefficients (if Lawton or Lina-Mayrand wavelets are selected, otherwise this is NULL).
- `name`: A character string containing the name of the filter.
- `family`: A character string containing the family of the filter.
- `filter.number`: The filter number used to select the filter from within a family.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994. This version originally part of the cthresh release which was merged into wavethresh in Oct 2012. Original cthresh version due to Stuart Barber

Note

The (Daubechies) filter coefficients should always sum to $\sqrt{2}$. This is a useful check on their validity.

Author(s)

Stuart Barber and G P Nason

See Also

`wd, wr, wr.wd, accessC, accessD, compare.filters, imwd, imwr, threshold, draw`

Examples

#This function is usually called by others.
#However, on occasion you may wish to look at the coefficients themselves.

# look at the filter coefficients for N=4 (by default Daubechies' least-asymmetric wavelets.)
# filter.select(4)
#H:
#0.07576571 -0.02963553 0.49761867 0.80373875 0.29785780
find.parameters

Find estimates of prior parameters

Description

Estimate the prior parameters for the complex empirical Bayes shrinkage procedure.

Usage

find.parameters(data.wd, dwwt, j0, code, tol, Sigma)

Arguments

data.wd Wavelet decomposition of the data being analysed.
dwwt The diagonal elements of the matrix Wt(W). See make.dwwt for details.
j0 Primary resolution level, as discussed in the help for threshold.wd
code Tells the function whether to use NAG code for the search (code="NAG"), R/S-plus for the search with C code to evaluate the likelihood (code="C"), or R/S-plus code for all calculations (code="R" or code="S"). Setting code="NAG" is strongly recommended.
tol A tolerance parameter which bounds the mixing weight away from zero and one and the correlation between real and imaginary parts of the prior away from plus or minus one.
Sigma The covariance matrix of the wavelet coefficients of white noise.

Details

The complex empirical Bayes (CEB) shrinkage procedure described by Barber & Nason (2004) places independent mixture priors on each complex-valued wavelet coefficient. This routine finds marginal maximum likelihood estimates of the prior parameters. If the NAG library is available, routine E04JYF is used otherwise the search is done using optimize (in R) or nlminb (in S-plus). In the latter case, the likelihood values should be computed externally using the C code supplied as part of the CThresh package - although a pure R / S-plus version is available, it is very slow. This function will not usually be called directly by the user, but is called from within cthresh.
**Value**

A list with the following components:

pars  Estimates of the prior parameters. Each row of this matrix contains the following parameter estimates for one level of the transform: mixing weight; variance of the real part of the wavelet coefficients; covariance between the real and imaginary parts; variance of the imaginary part of the wavelet coefficients. Note that for levels below the primary resolution, this search is not done and the matrix is full of zeros.

Sigma  The covariance matrix as supplied to the function.

**RELEASE**

Part of the CThresh addon to WaveThresh. Copyright Stuart Barber and Guy Nason 2004.

**Note**

There may be warning messages from the NAG routine E04JYF. If the indicator variable IFAIL is equal to 5, 6, 7, or 8, then a solution has been found but there is doubt over the convergence. For IFAIL = 5, it is likely that the correct solution has been found, while IFAIL = 8 means that you should have little confidence in the parameter estimates. For more details, see the NAG software documentation available online at [http://www.nag.co.uk/numeric/fl/manual19/pdf/E04/e04jyf_fl19.pdf](http://www.nag.co.uk/numeric/fl/manual19/pdf/E04/e04jyf_fl19.pdf)

**Author(s)**

Stuart Barber

**See Also**

cthresh

---

**first.last**  
*Build a first/last database for wavelet transforms.*

**Description**

This function is not intended for user use, but is used by various functions involved in computing and displaying wavelet transforms. It basically constructs "bookeeping" vectors that WaveThresh uses for working out where coefficient vectors begin and end.

**Usage**

```r
first.last(LengthH, DataLength, type, bc="periodic", current.scale=0)
```
Arguments
LengthH  Length of the filter used to produce a wavelet decomposition.
DataLength  Length of the data before transforming. This must be a power of 2, say $2^m$.
type  The type of wavelet transform. Can be "wavelet" or "periodic"
bc  This character string argument determines how the boundaries of the function are to be handled. The permitted values are periodic or symmetric.
current.scale  Can handle a different initial scale, but usually left at the default

Details
Suppose you begin with $2^m = 2048$ coefficients. At the next level you would expect 1024 smoothed data coefficients, and 1024 wavelet coefficients, and if bc="periodic" this is indeed what happens. However, if bc="symmetric" you actually need more than 1024 (as the wavelets extend over the edges). The first last database keeps track of where all these "extras" appear and also where they are located in the packed vectors C and D of pyramidal coefficients within wavelet structures.

For examples, given a first.last.c row of

\[-2320\]

The actual coefficients would be

$c_{-2}, c_{-1}, c_0, c_1, c_2, c_3$

In other words, there are 6 coefficients, starting at -2 and ending at 3, and the first of these ($c_{-2}$) appears at an offset of 20 from the beginning of the $C$ component vector of the wavelet structure.

You can "do" first.last in your head for periodic boundary handling but for more general boundary treatments (e.g. symmetric) first.last is indispensable.

Value
A first/last database structure, a list containing the following information:

first.last.c  A (m+1)x3 matrix. The first column specifies the real index of the first coefficient of the smoothed data at a level, the 2nd column is the real index of the last coefficient, the last column specifies the offset of the first smoothed datum at that level. The offset is used by the C code to work out where the beginning of the sequence is within a packed vector of the pyramid structure. The first and 2nd columns can be used to work out how many numbers there are at a level. If bc="periodic" then the pyramid is a true power of 2 pyramid, that is it starts with a power of 2, and the next level is half of the previous. If bc="symmetric" then the pyramid is nearly exactly a power of 2, but not quite, see the Details section for why this is so.

ntotal  The total number of smoothed data/original data points.

first.last.d  A mx3 matrix. As for first.last.c but for the wavelet coefficients packed as the D component of a wavelet structure.

ntotal.d  The total number of wavelet coefficients.
RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

References


See Also

wd, wr, wr.wd, accessC, accessD, filter.select, imwd.

Examples

# If you're twisted then you may just want to look at one of these.
#
first.last(length(filter.select(2)), 64)
#$first.last.c:
#First Last Offset
#[1,] 0 0 126
#[2,] 0 1 124
#[3,] 0 3 120
#[4,] 0 7 112
#[5,] 0 15 96
#[6,] 0 31 64
#[7,] 0 63 0
#
#$ntotal:
#[1] 127
#
#$first.last.d:
#First Last Offset
#[1,] 0 0 62
#[2,] 0 1 60
#[3,] 0 3 56
#[4,] 0 7 48
#[5,] 0 15 32
#[6,] 0 31 0
#
#$ntotal.d:
#[1] 63
#
#
first.last.dh  

Build special first/last database for some wavelet density functions

Description

This function builds a special first/last database for some of the wavelet density estimation functions written by David Herrick and described in his PhD thesis.

See first.last to see what this kind of function does.

Usage

first.last.dh(LengthH, DataLength, type = "wavelet", bc = "periodic", firstk = c(0, DataLength - 1))

Arguments

LengthH        The length of the smoothing (C) filter
DataLength     The length of the data that you wish to transform
type           The type of wavelet transform, wavelet or station for decimated and nondecimated transforms respectively.
bc              Boundary conditions, periodic or symmetric
firstk         The first k index, leave as default

Details

Description says all.

Value

A list with several components in exactly the same format as for first.last.

Author(s)

David Herrick

See Also

dencvwd,first.last.wd.dh
firstdot  

Return the location of the first period character within a character string (for a vector of strings of arbitrary length).

Description

Returns the index of the location of the first period character within a character string for a series of strings in a vector of character string of arbitrary length).

This is a subsidiary routine for rmget and not really intended for user use.

Usage

firstdot(s)

Arguments

s    Vector of character strings.

Details

A very simple function. It searches through a character string for the first period character and the returns the position of that period character. It performs this search for each of the character strings in the input vector.

Value

A vector of integers of the same length as the input vector. Each integer in the output vector is the index position of the first period character in the corresponding character string in the input vector. If a character string does not contain a period character then the corresponding output integer is zero.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

References


See Also

rmget
Examples

```r
# Let's find the first dot in the following strings...
#
# firstdot("mary.had.a.little.lamb")
#[1] 5  
# I.e. the first period was after "mary" -- the fifth character
# This following string doesn't have any periods in it.
# firstdot("StellaArtois")
#[1] 0
#
# The function works on vectors of character strings
#
# firstdot(TopCricketAve)
#[1] 4 7 7 8 6 6
```

FullWaveletCV  
Perform whole wavelet cross-validation in C code

Description

Perform whole wavelet cross-validation in C code. This routine equivalent to CWCV except that more preparatory material is passed to C code for speed.

The major difference is that only the cross-validated wavelet threshold is returned.

Usage

```r
FullWaveletCV(noisy, ll = 3, type = "soft", filter.number = 10, family =
"DaubLeAsymm", tol = 0.01, verbose = 0)
```

Arguments

- **noisy**: A vector of dyadic (power of two) length that contains the noisy data that you wish to apply wavelet shrinkage by cross-validation to.
- **ll**: The primary resolution that you wish to assume. No wavelet coefficients that are on coarser scales than ll will be thresholded.
- **type**: this option specifies the thresholding type which can be "hard" or "soft".
- **filter.number**: This selects the smoothness of wavelet that you want to perform wavelet shrinkage by cross-validation.
- **family**: specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
tol this specifies the convergence tolerance for the cross-validation optimization routine (a golden section search).

verbose Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.

Details
Description says all

Value
The cross-validated wavelet threshold.

Author(s)
G P Nason

See Also
CWCV

Description
This function generates a matrix that can perform the discrete wavelet transform (useful for understanding the DWT but use the fast algorithm coded in wd for general use). The function returns the matrix for the inverse transform. Since the matrix is orthogonal transpose the matrix to obtain the forward transform matrix.

Usage
GenW(n=8, filter.number=10, family="DaubLeAsymm", bc="periodic")

Arguments
n The order of the DWT matrix will be n times n. n should be a power of two.

filter.number This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

bc boundary conditions to use. This can be periodic or symmetric depending on whether you want the returned matrix to assume periodic or symmetric end-reflection boundary conditions.
The discrete wavelet transform is usually computed using the fast pyramid algorithm of Mallat. However, the transform can be written in a matrix form and this is useful for understanding what the fast transform does. One wouldn’t normally use the matrix for performing the transform but use the fast transform function \texttt{wd} instead.

The matrix returned by this function represents the inverse DWT. Since the matrix (and transform) is orthogonal one can obtain the matrix representation of the forward transform simply by transposing the matrix using the \texttt{t} function in S-Plus.

The returned matrix is organised as follows. The first column always corresponds to the linear combination corresponding to the scaling function coefficient (so the column is constant. The next \(n/2\) columns correspond to the finest scale wavelet coefficients; the next \(n/4\) columns to the next finest scale and so on until the last column which corresponds to the coarsest scale wavelet coefficients.

The matrix is computed by performing successive fast DWTs on unit vectors.

Value

A matrix of order \(n\) that contains the inverse discrete wavelet transform.

RELEASE

Version 3.2 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

\texttt{wd, wr}.

Examples

```r
# Generate the wavelet transform matrix corresponding to the Haar wavelet
# transform of order 8
#
# Let's look at this matrix

# Generate wavelet transform matrix for Haar wavelet of order 8
haarmat <- GenW(8, filter.number=1, family="DaubExPhase")
# Let's look at this matrix
haarmat
```

```r
#[1,] 0.3535534 0.7071068 0.0000000 0.0000000 0.0000000 0.5 0.0 0.3535534  
#[2,] 0.3535534 -0.7071068 0.0000000 0.0000000 0.0000000 0.5 0.0 0.3535534  
#[3,] 0.3535534 0.0000000 0.7071068 0.0000000 0.0000000 -0.5 0.0 0.3535534  
#[4,] 0.3535534 0.0000000 -0.7071068 0.0000000 0.0000000 -0.5 0.0 0.3535534  
#[5,] 0.3535534 0.0000000 0.0000000 0.7071068 0.0000000 0.0 0.5 -0.3535534  
#[6,] 0.3535534 0.0000000 0.0000000 -0.7071068 0.0000000 0.0 0.5 -0.3535534  
#[7,] 0.3535534 0.0000000 0.0000000 0.0000000 0.7071068 0.0 -0.5 -0.3535534  
#[8,] 0.3535534 0.0000000 0.0000000 0.0000000 -0.7071068 0.0 -0.5 -0.3535534  
```
As noted above the first column is the l.c. corresponding to the scaling function coefficient and then the l.c.s corresponding to the wavelet coefficients from the finest to the coarsest.

The above matrix represented the inverse DWT. Let's compute the forward transform matrix representation:

```
getarrvec(nlevels, sort=TRUE)
```

The `getarrvec` function computes weaving permutation for conversion from `wst` objects to `wd` class objects. It takes two arguments:

- `nlevels`: The number of levels in the non-decimated transform for which the permutation is to be computed.
- `sort`: If TRUE then compute permutation for indexing a `wst` object. If FALSE then compute permutation for indexing a `wd` object.

Conversion of `wst` objects into `wd` objects and vice versa can be carried out using the `convert.wst` and `convert.wd` functions. These latter functions depend on this `getarrvec` function to compute the permutation which maps coefficients from one ordering to the other.

This function returns a matrix which gives the necessary permutations for scale levels 1 to `nlevels`-1. If you want to get the permutation for the level 0 coefficients of the `wst` object you will have to call the `levarr` function directly.
This permutation is described in Nason, Sapatinas and Sawczenko, 1998.
The function that actually computes the permutations is `levarr`. This function just combines the results from `levarr`.

**Value**
A matrix with `nlevels-1` columns. Column 1 corresponds to scale level `nlevels-1` in the `wst` object, and column `nlevels-1` corresponds to scale level 1 in the `wst` object. Replace `wst` by `wd` if `sort=FALSE`.

**RELEASE**
Version 3.6 Copyright Guy Nason 1997

**Author(s)**
G P Nason

**See Also**
`convert`, `convert.wd`, `convert.wst`, `levarr`, `wst`, `wst.object`, `wpst`.

**Examples**
```
# What would the permutation be for a wst object with 4 levels?
#
# arrvec <- getarrvec(4)
# arrvec
#
# [1,] 1 1 1 1
# [2,] 9 9 9 9
# [3,] 2 5 2 5
# [4,] 10 13 10 13
# [5,] 3 2 3 2
# [6,] 11 10 11 10
# [7,] 4 6 7 4
# [8,] 12 14 15 12
# [9,] 5 3 2 5
# [10,] 13 11 10 13
# [11,] 6 7 6 7
# [12,] 14 15 14 15
# [13,] 7 4 7 4
# [14,] 15 12 15 12
# [15,] 8 8 8 8
# [16,] 16 16 16 16
#
# The permutation for level 3 is in column 1
# The permutation for level 2 is in column 2
# The permutation for level 1 is in column 3.
```
getpacket

Get a packet of coefficients from a wavelet object

Description

This generic function extracts packets of coefficients from various types of wavelet objects. This function is generic.
Particular methods exist. For objects of class:

**wp** use the `getpacket.wp` method.

**wst** use the `getpacket.wst` method.

**wpst** use the `getpacket.wpst` method.

See individual method help pages for operation and examples.

Use the `accessC` and `accessD` function to extract whole resolution levels of coefficients simultaneously.

**Usage**

```r
getpacket(...) 
```

**Arguments**

... See individual help pages for details.

**Value**

The packet of coefficients requested.

**RELEASE**

Version 3.5.3 Copyright Guy Nason 1994

**Author(s)**

G P Nason

**See Also**

`getpacket.wp`, `getpacket.wst`, `getpacket.wpst`, `accessD`, `accessC`.

---

**getpacket.wp**  
*Get packet of coefficients from a wavelet packet object (wp).*

**Description**

This function extracts and returns a packet of coefficients from a wavelet packet (**wp**) object.

**Usage**

```r
## S3 method for class 'wp'
getpacket(wp, level, index, ...) 
```
Arguments

- `wp`: Wavelet packet object from which you wish to extract the packet from.
- `level`: The resolution level of the coefficients that you wish to extract.
- `index`: The index number within the resolution level of the packet of coefficients that you wish to extract.
- ... any other arguments

Details

The `wp` produces a wavelet packet object. The coefficients in this structure can be organised into a binary tree with each node in the tree containing a packet of coefficients.

Each packet of coefficients is obtained by chaining together the effect of the two packet operators DG and DH: these are the high and low pass quadrature mirror filters of the Mallat pyramid algorithm scheme followed by decimation (see Mallat-(1989b)).

Starting with data \( c^J \) at resolution level \( J \) containing \( 2^J \) data points the wavelet packet algorithm operates as follows. First DG and DH are applied to \( c^J \) producing \( d^{J-1} \) and \( c^{J-1} \) respectively. Each of these sets of coefficients is of length one half of the original data: i.e. \( 2^{J-1} \). Each of these sets of coefficients is a set of wavelet packet coefficients. The algorithm then applies both DG and DH to both \( d^{J-1} \) and \( c^{J-1} \) to form a four sets of coefficients at level \( J-2 \). Both operators are used again on the four sets to produce 8 sets, then again on the 8 sets to form 16 sets and so on. At level \( j=J,...,0 \) there are \( 2^{J-j} \) packets of coefficients each containing \( 2^j \) coefficients.

This function enables whole packets of coefficients to be extracted at any resolution level. The index argument chooses a particular packet within each level and thus ranges from 0 (which always refer to the father wavelet coefficients), 1 (which always refer to the mother wavelet coefficients) up to \( 2^{J-j} \).

Value

A vector containing the packet of wavelet packet coefficients that you wished to extract.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

`wp, putpacket.wp, basisplot.wp, draw.wp, InvBasis.wp, MaNoVe.wp, nlevelsWT.wp, plot.wp, threshold.wp`. 
Examples

```r
# Take the wavelet packet transform of some random data
# MyWP <- wp(rnorm(1:512))
# The above data set was 2^9 in length. Therefore there are
# coefficients at resolution levels 0, 1, 2, ..., and 8.
# The high resolution coefficients are at level 8.
# There should be 256 DG coefficients and 256 DH coefficients
# length(getpacket(MyWP, level=8, index=0))
#[1] 256
length(getpacket(MyWP, level=8, index=1))
#[1] 256
# The next command shows that there are only two packets at level 8
## Not run: getpacket(MyWP, level=8, index=2)
# Index was too high, maximum for this level is 1
# Error in getpacket.wp(MyWP, level = 8, index = 2): Error occured
# Dumped
# There should be 4 coefficients at resolution level 2
# The father wavelet coefficients are (index=0)
getpacket(MyWP, level=2, index=0)
#[1] -0.9736576 0.5579501 0.3100629 -0.3834068
# The mother wavelet coefficients are (index=1)
#[1] 0.72871405 0.04356728 -0.43175307 1.77291483
# There will be 127 packets at this level.
```

getpacket.wpst

:Get packet of coefficients from a non-decimated wavelet packet object (wpst).

Description

This function extracts and returns a packet of coefficients from a non-decimated wavelet packet (wpst) object.

Usage

```
## S3 method for class 'wpst'
getpacket(wpst, level, index, ...)
```
Arguments

wpst Non-decimated wavelet packet object from which you wish to extract the packet from.

level The resolution level of the coefficients that you wish to extract. Can range from 0 to nlevelsWT(wpst). The coefficients at level nlevels are the data the created the wpst.object.

index The index number within the resolution level of the packet of coefficients that you wish to extract. Index ranges from 0 to \(4^r - 1\) where \(r = nlevelsWT - level\).

... any other arguments

Details

The wpst transform produces a non-decimated wavelet packet object. This is a "cross" between a wavelet packet object and a non-decimated wavelet object. In other words the transform produces wavelet packet coefficients at every possible integer shift (unlike the ordinary wavelet packet transform which is aligned to a dyadic grid).

Each packet of coefficients is obtained by chaining together the effect of the two packet operators DG and DH: these are the high and low pass quadrature mirror filters of the Mallat pyramid algorithm scheme followed by both even and odd decimation. For a full description of this algorithm and how coefficients are stored within see Nason, Sapatinas and Sawczenko, 1998.

Note that this function extracts packets. If you want to obtain the wavelet packet coefficients for each shift you need to use the accessD.wpst function. This function extracts particular wavelet packet coefficients for a particular shift. In particular, this function returns a number of coefficients dependent on the scale level requested whereas accessD.wpst always returns a vector of coefficients of length equal to the input data that created the wpst.object initially.

Value

A vector containing the packet of non-decimated wavelet packet coefficients that you wished to extract.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

accessD.wpst, wpst,
Examples

# Create some random data
myrand <- rnorm(16)

# Do the non-decimated wavelet packet transform
myrwpst <- wpst(myrand)

# Let's access what is a level
getpacket(myrwpst, nlevelsWT(myrwpst), index=0)

# I.e. the data that created the object.

# How about extracting the 3rd (last) packet at level 3?
getpacket(myrwpst, 3, index=3)

# Of course, there are only 8 coefficients at this level.

getpacket.wst

Get packet of coefficients from a packet ordered non-decimated wavelet object (wst).

Description

This function extracts and returns a packet of coefficients from a packet-ordered non-decimated wavelet object (wst) object. The wst objects are computed by the wst function amongst others.

Usage

## S3 method for class 'wst'
getpacket(wst, level, index, type="D", aspect, ...)
Arguments

- **wst**: Packet-ordered non-decimated wavelet object from which you wish to extract the packet from.
- **level**: The resolution level of the coefficients that you wish to extract.
- **index**: The index number within the resolution level of the packet of coefficients that you wish to extract.
- **type**: This argument must be either "C" or "D". If the argument is "C" then non-decimated father wavelet coefficients corresponding to the packet that you want are returned. If the argument is "D" then non-decimated mother wavelet coefficients are returned.
- **aspect**: Function applied to the coefficients before return. This is supplied as a character string which gets converted to a function to apply. For example, "Mod" for complex-valued coefficients returns the absolute values.
- **...**: Other arguments

Details

The **wst** function produces a packet-ordered non-decimated wavelet object: **wst**. The coefficients in this structure can be organised into a binary tree with each node in the tree containing a packet of coefficients.

Each packet is obtained by repeated application of the usual DG quadrature mirror filter with both even and odd dyadic decimation. See the detailed description given in Nason and Silverman, 1995.

This function enables whole packets of coefficients to be extracted at any resolution level. The index argument chooses a particular packet within each level and thus ranges from 0 to \(2^{J-j}\) for \(j=0,...,J-1\). Each packet corresponds to the wavelet coefficients with respect to different origins.

Note that both mother and father wavelet coefficient at different shifts are available by using the type argument.

Value

A vector containing the packet of packet-ordered non-decimated wavelet coefficients that you wished to extract.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

**wst**, **wst.object**
getpacket.wst2D

Get packet of coefficients from a two-dimensional non-decimated wavelet object (wst2D).

Description

This function extracts and returns a packet of coefficients from a two-dimensional non-decimated wavelet (wst2D) object.

Usage

```r
## S3 method for class 'wst2D'
getpacket(wst2D, level, index, type="S", Ccode=TRUE, ...)
```
Arguments

- **wst2D**: 2D non-decimated wavelet object from which you wish to extract a packet from.
- **level**: The resolution level of the coefficients that you wish to extract. Can range from 0 to \(n\text{levelsWT}(wst)-1\).
- **index**: The index number within the resolution level of the packet of coefficients that you wish to extract. Index is a base-4 number which is \(r\) digits long. Each digit can be 0, 1, 2 or 3 corresponding to no shifts, horizontal shift, vertical shift or horizontal and vertical shifts. The number \(r\) indicates the depth of the resolution level from the data resolution i.e. where \(r = n\text{levelsWT} - \text{level}\). Where there is a string of more than one digit the left most digits correspond to finest scale shift selection, the right most digits to the coarser scales (I think).
- **type**: This is a one letter character string: one of "S", "H", "V" or "D" for the smooth coefficients, horizontal, vertical or diagonal detail.
- **Ccode**: If `T` then fast C code is used to obtain the packet, otherwise slow SPlus code is used. Unless you have some special reason always use the C code (and leave the argument at its default).
- ... any other arguments

Details

The **wst2D** function creates a **wst2D** class object. Starting with a smooth the operators H, G, GS and HS (where G, H are the usual Mallat operators and S is the shift-by-one operator) are operated first on the rows and then the columns: i.e. so each of the operators HH, HG, GH, GG, HSH, HSG, GSH, GSG HHS, GHS, HGS, GGS HSHS, HSGS, GSHS and GSGS are applied. Then the same collection of operators is applied to all the derived smooths, i.e. HH, HSH, HHS and HSHS. So the next level is obtained from the previous level with basically HH, HG, GH and GG but with extra shifts in the horizontal, vertical and horizontal and vertical directions. The index provides a way to enumerate the paths through this tree where each smooth has 4 children and indexed by a number between 0 and 3.

Each of the 4 children has 4 components: a smooth, horizontal, vertical and diagonal detail, much in the same way as for the Mallat 2D wavelet transform implemented in the WaveThresh function **imwd**.

Value

A matrix containing the packet of the 2D non-decimated wavelet coefficients that you require.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason
See Also

\texttt{putpacket.wst2D, wst2D, wst2D.object}.

Examples

\begin{verbatim}
# Create a random image.
#
myrand <- matrix(rnorm(16), nrow=4, ncol=4)
#myrand
#
#[1,]  0.01692807  0.1400891 -0.38225727  0.3372708
#[2,] -0.79799841 -0.3306080  1.59789958 -1.0606204
#[3,]  0.29151629 -0.2028172 -0.02346776  0.5833292
#[4,] -2.21505532 -0.3591296 -0.39354119  0.6147043
#
# Do the 2D non-decimated wavelet transform
#
myrwst2D <- wst2D(myrand)
#
# Let's access the finest scale detail, not shifted in the vertical
# direction.
#
getpacket(myrwst2D, nlevelsWT(myrwst2D)-1, index=0, type="V")
#
#[,1] [,2]
#[1,] -0.1626819 -1.3244064
#
# Compare this to the ordinary 2D DWT for the vertical detail at this
# resolution level

imwd(myrand)[[lt.to.name( 1, "DC")]]

#[,1] -0.1626819 -1.3244064  1.4113247 -0.7383336
#
# The same numbers but they're not in matrix format because
# imwd returns vectors not matrices.
#
# Now back to the wst2D object. Let's
#
# extract vertical detail again at level 1 but this time the horizontally
# shifted data.
#
getpacket(myrwst2D, level=1, index=1, type="V")
#
#[,1] [,2]
#[1,]  0.5984427  0.2599445
#[2,] -0.6502002  1.8027955
#
# So, yes, different data. Now how about at a deeper resolution level.
#
# Let's have a horizontal shift, as before, for the level 1 but follow it
#
# with a diagonal shift and this time extract the smooth component:
#
getpacket(myrwst2D, level=0, index=13, type="S")
#
#[,1]
#[1,] -0.5459394
#\end{verbatim}
# Of course, only one number because this is at level 0

---

**GetRSSWST**  
*Computes estimate of error for function estimate.*

**Description**

Computes estimate of error for function estimate. Given noisy data and a threshold value this function uses Nason’s 1996 two-fold cross-validation algorithm, but using packet ordered non-decimated wavelet transforms to compute two estimates of an underlying “true” function and uses them to compute an estimate of the error in estimating the truth.

**Usage**

```r
GetRSSWST(ndata, threshold, levels, family = "DaubLeAsymm", filter.number = 10, type = "soft", norm = l2norm, verbose = 0, InverseType = "average")
```

**Arguments**

- `ndata`: the noisy data. This is a vector containing the signal plus noise. The length of this vector should be a power of two.
- `threshold`: the value of the threshold that you wish to compute the error of the estimate at
- `levels`: the levels over which you wish the threshold value to be computed (the threshold that is used in computing the estimate and error in the estimate). See the explanation for this argument in the `threshold.wst` function.
- `family`: specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
- `filter.number`: This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.
- `type`: whether to use hard or soft thresholding. See the explanation for this argument in the `threshold.wst` function.
- `norm`: which measure of distance to judge the dissimilarity between the estimates. The functions `l2norm` and `linfnorm` are suitable examples.
- `verbose`: If TRUE then informative messages are printed during the progression of the function, otherwise they are not.
- `InverseType`: The possible options are "average" or "minent". The former uses basis averaging to form estimates of the unknown function. The "minent" function selects a basis using the Coifman and Wickerhauser, 1992 algorithm to select a basis to invert.
Details

This function implements the component of the cross-validation method detailed by Nason, 1996 for computing an estimate of the error between an estimate and the "truth". The difference here is that it uses the packet ordered non-decimated wavelet transform rather than the standard Mallat \texttt{wd} discrete wavelet transform. As such it is an example of the translation-invariant denoising of Coifman and Donoho, 1995 but uses cross-validation to choose the threshold rather than SUREshrink.

Note that the procedure outlined above can use \texttt{AvBasis} basis averaging or basis selection and inversion using the Coifman and Wickerhauser, 1992 best-basis algorithm.

Value

A real number which is estimate of the error between estimate and truth at the given threshold.

RELEASE

Version 3.6 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

\texttt{linfnorm}, \texttt{linfnorm}, \texttt{wstCV}, \texttt{wstCVl}.

Examples

```r
#
# This function performs the error estimation step for the
# \code{\link{wstCV}} function and so is not intended for
# user use.
#
```

---

griddata objects

Data interpolated to a grid objects.

Description

These are objects of classes

\texttt{griddata}

These objects store the results of interpolating a 1-D regression data set to a grid which is a power of two in length.
Details

The help page for `makegrid` and Kovac, (1997), p.81 give further details about how a griddata object is constructed.

Value

The following components must be included in a legitimate griddata object.

- `gridt`: a vector containing the values of the grid on the "x" axis.
- `gridy`: a vector containing the values of the grid on the "y" axis. This vector has to be the same length as `gridt`. Typically the values in `(gridt, gridy)` are the results of interpolating arbitrary data `(x,y)` onto `(gridt, gridy)`.
- `G`: Codes the value of the linear interpolant matrix for the corresponding entry in `gridt`. The value at each point corresponds to the proportion of the original data point pointed to by `Gindex` that contributes to the new value at the corresponding `gridt` value. See Kovac, (1997), page 81 for further information.
- `Gindex`: Each entry in `Gindex` refers to one of the pairs in `(x,y)` which is contributing to the `(gridt, gridy)` interpolant. See previous help for `G`.

GENERATION

This class of objects is returned from the `makegrid` function to represent the results of interpolating a 1-D regression data set to a grid.

METHODS

The `griddata` class of objects really on has one function that uses it: `irregwd`.

RELEASE

Version 3.9.6 Copyright Arne Kovac 1997 Copyright Guy Nason (help pages) 1999.

SEE ALSO

- `makegrid`, `irregwd`

Author(s)

Arne Kovac
guyrot

Cyclically rotate elements of a vector

Description

This function shifts (or rotates) the elements of the input vector in a cyclic fashion (end periodicity is used).

Usage

guyrot(v, n)

Arguments

v Vector whose elements you wish to rotate
n Integer determining the amount to rotate, can be negative

Details

A very simple function which cyclically shifts the elements of a vector. Not necessarily intended as a top level user function but it is a useful little function.

Value

A vector containing the shifted or rotated coefficients.

Author(s)

G P Nason

See Also

wpst2discr, wpstCLASS

Examples

# Start off with an example vector
v <- c(1,2,3,4,5,6)
# Rotate it one element to the right, rightmost element gets rotated round # to be first element.
# guyrot(v,1)
# [1] 6 1 2 3 4 5
# # Rotate v two spaces to the left, leftmost two elements get rotated around # to be new last elements
HaarConcat

Generate a concatenated Haar MA process

Description

This function generates a particular set of four concatenated Haar MA processes.

Usage

HaarConcat()

Arguments

None

Details

This function generates a realization of particular kind of non-stationary time series probability model. The returned time series is the result of concatenating 4 time series each of length 128 from the Haar MA process generator (HaarMA) of orders 1, 2, 3 and 4. The standard deviation of the innovations is 1. This function was used to generate the figure of the concatenated Haar MA process in Nason, von Sachs and Kroisandt. It produces a kind of time series that can be sparsely represented by the wavelet machinery but at the same time is non-stationary.


Value

A vector containing 512 observations from four concatenated Haar MA processes

Author(s)

G P Nason
See Also

HaarMA, ewspecc

Examples

```r
# Generate the concatenated Haar MA process.
# MyHaarCC <- HaarConcat()
# # Plot it
# ## Not run: ts.plot(MyHaarCC)
```

HaarMA

Generate Haar MA processes.

Description

This function generates an arbitrary number of observations from a Haar MA process of any order with a particular variance.

Usage

HaarMA(n, sd=1, order=5)

Arguments

- **n**: The number of observations in the realization that you want to create. Note that n does NOT have to be a power of two.
- **sd**: The standard deviation of the innovations.
- **order**: The order of the Haar MA process.

Details

A Haar MA process is a special kind of time series moving-average (MA) process. A Haar MA process of order k is a MA process of order $2^k$. The coefficients of the Haar MA process are given by the filter coefficients of the discrete Haar wavelet at different scales.

For examples: the Haar MA process of order 1 is an MA process of order 2. The coefficients are $1/\sqrt{2}$ and $-1/\sqrt{2}$. The Haar MA process of order 2 is an MA process of order 4. The coefficients are $1/2$, $1/2$, $-1/2$, $-1/2$ and so on. It is possible to define other processes for other wavelets as well.

Any Haar MA process is a good examples of a (stationary) LSW process because it is sparsely representable by the locally-stationary wavelet machinery defined in Nason, von Sachs and Kroisandt.

Value

A vector containing a realization of a Haar MA process of the specified order, standard deviation and number of observations.
HaarMA

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

References


See Also

HaarConcat, ewspect.

Examples

```r
# Generate a Haar MA process of order 1 (high frequency series)
#
MyHaarMA <- HaarMA(n=151, sd=2, order=1)
# # Plot it
#
## Not run: ts.plot(MyHaarMA)
#
# Generate another Haar MA process of order 3 (lower frequency), but of
# smaller variance
#
MyHaarMA2 <- HaarMA(n=151, sd=1, order=3)
# # Plot it
#
## Not run: ts.plot(MyHaarMA2)
#
# Let's plot them next to each other so that you can really see the
# differences.
#
# Plot a vertical dotted line which indicates where the processes are
# joined
#
## Not run: ts.plot(c(MyHaarMA, MyHaarMA2))
## Not run: abline(v=152, lty=2)
```
image.wd

Produce image representation of nondecimated wavelet transform

### Description

Produces a representation of a nondecimated wavelet transform (time-ordered) as an image.

### Usage

```r
## S3 method for class 'wd'
image(x, strut = 10, type = "D", transform = I, ...)
```

### Arguments

- **x**: The `wd.object` that you wish to image.
- **strut**: The width of each coefficient in the image.
- **type**: Either "C" or "D" depending if you wish to image scaling function or wavelet coefficients respectively.
- **transform**: Apply a numerical transform to the coefficients before display.
- **...**: Other arguments.

### Details

Description says all.

### Value

None.

### Author(s)

G P Nason

### See Also

- `logabs`, `nlevelsWT.wd`

### Examples

```r
tmp <- wd(rnorm(256), type="station")
## Not run: image(tmp)
```
Produce image representation of a wst class object

Description

Produces an image representation of the coefficients contained within a \texttt{wst.object} class object.

Usage

```r
## S3 method for class 'wst'
image(x, nv, strut = 10, type = "D", transform = I, ...)
```

Arguments

- \texttt{x} The wst object you wish to image
- \texttt{nv} An associated node vector, this argument is no longer used and should be omitted (in the S version it permitted coloration of particular bases)
- \texttt{strut} The number of pixels/width that each coefficient should be drawn with
- \texttt{type} Either "C" or "D" depending on whether you wish to image scaling function coefficients or wavelet ones
- \texttt{transform} A numerical transform you wish to apply to the coefficients before imaging
- \texttt{...} Other arguments

Details

Description says all

Value

None

Author(s)

G P Nason

See Also

- \texttt{logabs.wst}

Examples

```r
tmp <- wst(rnorm(1024))
## Not run: image(tmp)
## Not run: image(tmp, transform=logabs)
```
imwd

Two-dimensional wavelet transform (decomposition).

Description

This function can perform two types of two-dimensional discrete wavelet transform (DWT). The standard transform (type="wavelet") computes the 2D DWT according to Mallat's pyramidal algorithm (Mallat, 1989). The spatially ordered non-decimated 2D DWT (NDWT) (type="station") contains all possible spatially shifted versions of the DWT. The order of computation of the DWT is O(n), and it is O(n log n) for the NDWT if n is the number of pixels.

Usage

imwd(image, filter.number=10, family="DaubLeAsymm", type="wavelet", bc="periodic", RetFather=TRUE, verbose=FALSE)

Arguments

image
A square matrix containing the image data you wish to decompose. The side-length of this matrix must be a power of 2.

filter.number
This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family
specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

type
specifies the type of wavelet transform. This can be "wavelet" (default) in which case the standard 2D DWT is performed (as in previous releases of WaveThresh). If type is "station" then the 2D spatially-ordered non-decimated DWT is performed. At present, only periodic boundary conditions can be used with the 2D spatially-ordered non-decimated wavelet transform.

bc
specifies the boundary handling. If bc="periodic" the default, then the function you decompose is assumed to be periodic on it's interval of definition, if bc="symmetric" then the function beyond its boundaries is assumed to be a symmetric reflection of the function in the boundary. The symmetric option was the implicit default in releases prior to 2.2. Note that only periodic boundary conditions are valid for the 2D spatially-ordered non-decimated wavelet transform.

RetFather
If TRUE then this argument causes the scaling function coefficients at each resolution level to be returned as well as the wavelet coefficients. If FALSE then no scaling function coefficients are returned. The opportunity of returning father wavelet coefficients has been added since previous versions of WaveThresh.

verbose
Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
Details

The 2D algorithm is essentially the application of many 1D filters. First, the columns are attacked with the smoothing (H) and bandpass (G) filters, and the rows of each of these resultant images are attacked again with each of G and H, this results in 4 images. Three of them, GG, GH, and HG correspond to the highest resolution wavelet coefficients. The HH image is a smoothed version of the original and can be further attacked in exactly the same way as the original image to obtain GG(HH), GH(HH), and HG(HH), the wavelet coefficients at the second highest resolution level and HH(HH) the twice-smoothed image, which then goes on to be further attacked.

If RetFather=TRUE then the results of the HH smooth (the scaling function coefficients) are returned additionally.

There are now two methods of handling "boundary problems". If you know that your function is periodic (on it's interval) then use the bc="periodic" option, if you think that the function is symmetric reflection about each boundary then use bc="symmetric". If you don't know then it is wise to experiment with both methods, in any case, if you don't have very much data don't infer too much about your decomposition! If you have loads of data then don't worry too much about the boundaries. It can be easier to interpret the wavelet coefficients from a bc="periodic" decomposition, so that is now the default.

The spatially-ordered non-decimated DWT contains all spatial (toroidal circular) shifts of the standard DWT.

The standard DWT is orthogonal, the spatially-ordered non-decimated transform is most definitely not. This has the added disadvantage that non-decimated wavelet coefficients, even if you supply independent normal noise. This is unlike the standard DWT where the coefficients are independent (normal noise).

The two-dimensional packet-ordered non-decimated discrete wavelet transform is computed by the wst2D function.

Value

An object of class imwd.object containing the two-dimensional wavelet transform (possibly spatially-ordered non-decimated).

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Author(s)

G P Nason

See Also

wd, imwd.object, filter.select

Examples

data(lennon)
#
# Let's use the lennon test image
# Not run: image(lennon)
#
# Now let's do the 2D discrete wavelet transform
#
# lwd <- imwd(lennon)
#
# Let's look at the coefficients
#
## Not run: plot(lwd)

---

**imwd.object**: *Two-dimensional wavelet decomposition objects.*

### Description

These are objects of classes `imwd` representing a decomposition of an image with respect to a two-dimensional wavelet basis (or tight frame in the case of the two-dimensional (space-ordered) non-decimated wavelet decomposition).

### Details

In previous releases the original image was stored as the "original" component of a `imwd` object. This is not done now as the resulting objects were excessively large.

### Value

The following components must be included in a legitimate ‘imwd’ object.

- `nlevelsWT` number of levels in wavelet decomposition. If you raise 2 to the power of `nlevels` then you get the dimension of the image that you originally started with.

- `type` If `type="wavelet"` then the image was decomposed according to the 2D Mallat pyramidal algorithm. If `type="station"` then the image was decomposed using the 2D spatially ordered non-decimated wavelet transform.

- `fl.dbase` The first last database associated with the decomposition. For images, this list is not very useful as each level’s components is stored as a list component, rather than being packaged up in a single vector as in the 1D case. Nevertheless the internals still need to know about `fl.dbase` to get the computations correct. See the help for `first.last` if you are a masochist.

- `filter` A filter object as returned by the `filter.select` function. This component records the filter used in the decomposition. The reconstruction routines use this component to find out what filter to use in reconstruction.
The object will probably contain many components with names of this form. These are all the wavelet coefficients of the decomposition. In "wNLx" the "N" refers to the level number and the "x" refers to the direction of the coefficients with "1" being horizontal, "2" being vertical and "3" being diagonal and "4" corresponding to scaling function coefficients at the given resolution level. Note that the levels should be in numerically decreasing order, so if nlevelsWT is 5, then there will be w5L1, w5L2, w5L3 first, then down to w1L1, w1L2, and w1L3. Note that these coefficients store their data according to the first.last database fl.dbase$first.last.d, so refer to them using this. Note that if type="wavelet" then images at level N are subimages of side length 2^N pixels. If the type component is "station" then each coefficient subimage is of the same dimension as the input image used to create this object.

This is the coefficient of the bottom level scaling function coefficient. So for examples, if you used Haar wavelets this would be the sample mean of the data (scaled by some factor depending on the number of levels, nlevelsWT).

This component details how the boundaries were treated in the decomposition.

**GENERATION**

This class of objects is returned from the `imwd` function to represent a two-dimensional (possibly space-ordered non-decimated) wavelet decomposition of a function. Many other functions return an object of class `imwd`.

**METHODS**

The `imwd` class of objects has methods for the following generic functions: `compress`, `draw`, `imwr`, `nullevels.imwd`, `plot`, `print`, `summary`, `threshold.imwd`.

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**Author(s)**

G P Nason

**See Also**

`imwd`
Details

In previous releases the original image was stored as the "original" component of an imwd object. This is not done now as the resulting objects were excessively large.

To uncompress this class of object back into an object of class imwd.object use the uncompress.imwdc function.

Value

The following components must be included in a legitimate `imwdc` object.

- **nlevelsWT**: number of levels in wavelet decomposition. If you raise 2 to the power of nlevels then you get the dimension of the image that you originally started with.

- **type**: If `type="wavelet"` then the image was decomposed according to the 2D Mallat pyramidal algorithm. If `type="station"` then the image was decomposed using the 2D spatially ordered non-decimated wavelet transform.

- **fl.dbase**: The first last database associated with the decomposition. For images, this list is not very useful as each level’s components is stored as a list component, rather than being packaged up in a single vector as in the 1D case. Nevertheless the internals still need to know about fl.dbase to get the computations correct. See the help for `first.last` if you are a masochist.

- **filter**: A filter object as returned by the `filter.select` function. This component records the filter used in the decomposition. The reconstruction routines use this component to find out what filter to use in reconstruction.

- **wNLx**: The object will probably contain many components with names of this form. These are all the wavelet coefficients of the decomposition. In "wNLx" the "N" refers to the level number and the "x" refers to the direction of the coefficients with "1" being horizontal, "2" being vertical and "3" being diagonal. Note that imwdc objects do not contain scaling function coefficients. This would negate the point of having a compressed object.

  Each vector stores its coefficients using an object of class compressed, i.e. the vector is run-length encoded on zeroes.

  Note that the levels should be in numerically decreasing order, so if nlevelsWT is 5, then there will be w5L1, w5L2, w5L3 first, then down to w1L1, w1L2, and w1L3. Note that these coefficients store their data according to the first.last database fl.dbase$first.last.d, so refer to them using this.

  Note that if type="wavelet" then images at level N are subimages of side length $2^N$ pixels. If the type component is "station" then each coefficient subimage is of the same dimension as the input image used to create this object.

- **w0Lconstant**: This is the coefficient of the bottom level scaling function coefficient. So for examples, if you used Haar wavelets this would be the sample mean of the data (scaled by some factor depending on the number of levels, nlevelsWT).

- **bc**: This component details how the boundaries were treated in the decomposition.
imwdc.object

GENERATION

This class of objects is returned from the `threshold.imwd` function to represent a thresholded two-dimensional wavelet decomposition of a function. Some other functions return an object of class `imwdc`.

METHODS

The `imwd` class of objects has methods for the following generic functions: `draw.imwd`, `nullevels`, `plot.imwd`, `print.imwd`, `summary.imwd`, `threshold.imwdc`.

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Author(s)

G P Nason

See Also

`imwd`, `imwd.object`, `threshold.imwd`, `uncompress.imwdc`

Examples

```r
# # Perform the standard two-dimensional DWT # on the lennon image. # data(lennon)

lwd <- imwd(lennon)
#
# Now let's see how many horizontal detail coefficients there are at # scale 6 #
length(lwd$w6L1)
# [1] 4096
#
# So the horizontal detail `image' at scale contains 64x64=4096 coefficients. # A lot!
#
# Now, suppose we threshold this # two-dimensional wavelet decomposition object #
lwdT <- threshold(lwd)
#
# First of all. What is the class of the detail coefficients now? #

class(lwdT$w6L1)
# [1] "compressed"
```
Inversion of a compressed dataset using the `imwr` function.

```r
# Aha. So this set of coefficients got compressed using the
# compress.default function.
#
# How many coefficients are being stored here?
#
# lwdT$w6L1
# $position:
# [1] 173 2829 2832 2846
# $values:
# [1] 141.5455 -190.2810 -194.5714 -177.1791
# $original.length:
# [1] 4096
# attr(, "class"):
# [1] "compressed"
#
# Wow! Only 4 coefficients are not zero. Wicked compression!
```

---

**Description**

Perform inverse two-dimensional wavelet transform using Mallat's, 1989 algorithm.

This function is generic.

Particular methods exist. For the `imwd` class object this generic function uses `imwr.imwd`. For the `imwdc` class object this generic function uses `imwr.imwdc`.

**Usage**

```r
imwr(...)```

**Arguments**

... See individual help pages for details.

**Details**

See individual method help pages for operation and examples.

**Value**

A square matrix whose side length is a power of two that represents the inverse 2D wavelet transform of the input object `x`. 
DESCRIPTION
This function performs the reconstruction stage of Mallat’s pyramid algorithm (i.e. the inverse discrete wavelet transform) for images.

USAGE
## S3 method for class 'imwd'
imwr(imwd, bc=imwd$bc, verbose=FALSE, ...)

ARGUMENTS
imwd An object of class ‘imwd'. This type of object is returned by ‘imwd'.
bc This argument specifies the boundary handling, it is best left to be the boundary handling specified by that in the supplied imwd (as is the default).
verbose If this argument is true then informative messages are printed detailing the computations to be performed
...
any other arguments

DETAILS
Details of the algorithm are to be found in Mallat (1989). Similarly to the decomposition function, imwd the inverse algorithm works by applying many 1D reconstruction algorithms to the coefficients. The filters in these 1D reconstructions are incorporated in the supplied imwd.object and originally created by the filter.select function in WaveThresh3.

This function is a method for the generic function imwr for class imwd.object. It can be invoked by calling imwr for an object of the appropriate class, or directly by calling imwr.imwd regardless of the class of the object.
Value

A matrix, of dimension determined by the original data set supplied to the initial decomposition (more precisely, determined by the `nlevelsWT` component of the `imwd.object`). This matrix is the highest resolution level of the reconstruction. If a `imwd` two-dimensional wavelet transform is followed immediately by a `imwr` inverse two-dimensional wavelet transform then the returned matrix will be exactly the same as the original image.

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Author(s)

G P Nason

See Also

`imwd`, `imwd.object`, `imwr`.

Examples

```r
# Do a decomposition, then exact reconstruction
# Look at the error
#
# test.image <- matrix(rnorm(32*32), nrow=32)
#
# Test image is just some sort of square matrix whose side length
# is a power of two.
#
# max( abs(imwr(imwd(test.image)) - test.image))
# [1] 1.014611e-11
```

---

**imwr.imwdc**

Inverse two-dimensional discrete wavelet transform.

**Description**

Inverse two-dimensional discrete wavelet transform.

**Usage**

```r
## S3 method for class 'imwdc'
imwr(imwd, verbose=FALSE, ...)
```
Arguments

imwd  
An object of class imwdc. This type of object is returned by threshold.imwd and is a compress.imwd compressed version of an imwd object.

verbose  
If this argument is true then informative messages are printed detailing the computations to be performed

...  
other arguments to supply to the imwr function which is called after uncompressing the imwdc object.

Details

This function merely uncompresses the supplied imwdc.object and passes the resultant imwd object to the imwr.imwd function.

This function is a method for the generic function imwr for class imwdc.object. It can be invoked by calling imwr for an object of the appropriate class, or directly by calling imwr.imwdc regardless of the class of the object.

Value

A matrix, of dimension determined by the original data set supplied to the initial decomposition (more precisely, determined by the nlevelsWT component of the imwdc.object). This matrix is the highest resolution level of the reconstruction.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

compress.imwd, imwd, imwd.object, imwr.

Examples

#  
# Do a decomposition, thresholding, then exact reconstruction  
# Look at the error  
#  
#  
test.image <- matrix(rnorm(32*32), nrow=32)

# Test image is just some sort of square matrix whose side length  
# is a power of two.  
#  
# max( abs(imwr(threshold(imwd(test.image))) - test.image)  
# [1] 62.34  
#
The answer is not zero (see contrasting examples in the help page for imwr.imwd because we have thresholded the 2D wavelet transform here).

---

**InvBasis**

*Generic basis inversion for libraries*

**Description**

Will invert either a wst or wp object given that object and some kind of basis specification.

**Usage**

```r
InvBasis(...)  
```

**Arguments**

... Usually a library representation and a basis specification

**Details**

Description says it all

**Value**

The reconstruction.

**Author(s)**

G P Nason

**See Also**

InvBasis.wp, InvBasis.wst, MaNoVe, numtonv
InvBasis.wp

Invert a wp library representation with a particular basis spec

Description

Inverts a wp basis representation with a given basis specification, for example an output from the MaNoVe function.

Usage

```r
## S3 method for class 'wp'
InvBasis(wp, nvwp, pktlist, verbose=FALSE, ...)
```

Arguments

- **wp**
  The wavelet packet object you wish to invert.
- **nvwp**
  A basis specification in the format of a node vector (wp) object, obtained, eg by the MaNoVe.wp function
- **pktlist**
  Another way of specifying the basis. If this argument is not specified then it is generated automatically from the nvwp argument. If it is specified then it overrides the one generated by nvwp
- **verbose**
  If TRUE then informative messages are printed.
- **...**
  Other arguments, not used

Details

Objects arising from a wp.object specification are a representation of a signal with respect to a library of wavelet packet basis functions. A particular basis specification can be obtained using the numtonv function which can pick an indexed basis function, or MaNoVe.wp which uses the Coifman-Wickerhauser minimum entropy method to select a basis. This function takes a wp.object and a particular basis description (in a nv.object node vector object) and inverts the representation with respect to that selected basis.

The function can alternatively take a packet list pktlist specification which overrides the node vector if supplied. If the pktlist is missing then one is generated internally from the nvwp object using the print.nvwp function.

Value

The inverted reconstruction

Author(s)

G P Nason

See Also

InvBasis, MaNoVe.wp, numtonv, print.nvwp
Examples

#
# The example in InvBasis.wst can be used here, but replaced wst by wp
#

---

**InvBasis.wst**

*Invert a wst library representation with a basis specification*

---

**Description**

Inverts a wst basis representation with a given basis specification, for example an output from the `MaNoVe` function.

**Usage**

```r
## S3 method for class 'wst'
InvBasis(wst, nv, ...)
```

**Arguments**

- `wst` The wst object that you wish to invert
- `nv` The node vector, basis spec, that you want to pick out
- `...` Other arguments, that don’t do anything here

**Details**

Objects arising from a `wst.object` specification are a representation of a signal with respect to a library of basis functions. A particular basis specification can be obtained using the `numtonv` function which can pick an indexed basis function, or `MaNoVe.wst` which uses the Coifman-Wickerhauser minimum entropy method to select a basis. This function takes a `wst.object` and a particular basis description (in a `nv.object` node vector object) and inverts the representation with respect to that selected basis.

**Value**

The inverted reconstruction

**Author(s)**

G P Nason

**See Also**

`numtonv,nv.object,MaNoVe.wst,threshold.wst,wst`
Examples

# Let's generate a noisy signal
#
x <- example.1()$y + rnorm(512, sd=0.2)
#
# You can plot this if you like
#
## Not run: ts.plot(x)
#
# Now take the nondecimated wavelet transform
#
xwst <- wst(x)
#
# Threshold it
#
xwstT <- threshold(xwst)
#
# You can plot this too if you like
#
## Not run: plot(xwstT)
#
# Now use Coifman-Wickerhauser to get a "good" basis
#
xwstTNV <- MaNoVe(xwstT)
#
# Now invert the thresholded wst using this basis specification
#
xTwr <- InvBasis(xwstT, xwstTNV)
#
# And plot the result, and superimpose the truth in dotted
#
## Not run: ts.plot(xTwr)
## Not run: lines(example.1()$y, lty=2)

ipd

Inductance plethysmography data.

Description

Inductance plethysmography trace.

Usage

data(ipd)

Author(s)

G P Nason
This data set contains 4096 observations of inductance plethysmography data sampled at 50Hz starting at 1229.98 seconds. This is a regular time series object.

I am grateful to David Moshal and Andrew Black of the Department of Anaesthesia, University of Bristol for permission to include this data set.

This data set was used in Nason, 1996 to illustrate noise reduction with wavelet shrinkage and using cross-validation for choosing the threshold.

A plethysmograph is an apparatus for measuring variations in the size of parts of the body. In this experiment the inductance plethysmograph consists of a coil of wire encapsulated in a belt. A radio-frequency carrier signal is passed through the wire and size variations change the inductance of the coil that can be detected as a change in voltage. When properly calibrated the output voltage of the inductance plethysmograph is proportional to the change in volume of the part of the body under examination.

It is of both clinical and scientific interest to discover how anaesthetics or analgesics may alter normal breathing patterns post-operatively. Sensors exist that measure blood oxygen saturation but by the time they indicate critically low levels the patient is often apnoeic (cease breathing) and in considerable danger. It is possible for a nurse to continually observe a patient but this is expensive, prone to error and requires training. In this examples the plethysmograph is arranged around the chest and abdomen of a set of patients and is used to measure the flow of air during breathing. The recordings below were made by the Department of Anaesthesia at the Bristol Royal Infirmary after the patients had undergone surgery under general anaesthetic. The data set (shown below) shows a section of plethysmograph recording lasting approximately 80 seconds. The two main sets of regular oscillations correspond to normal breathing. The disturbed behaviour in the centre of the plot where the normal breathing pattern disappears corresponds to the patient vomiting.

### Examples

```r
#
data(ipd)
## Not run: ts.plot(ipd)
```

### ipndacw

**Compute inner product matrix of discrete non-decimated autocorrelation wavelets.**

#### Description

This function computes the inner product matrix of discrete non-decimated autocorrelation wavelets.

#### Usage

```r
ipndacw(J, filter.number = 10, family = "DaubLeAsymm", tol = 1e-100, verbose = FALSE, ...)
```
Arguments

**J**
Dimension of inner product matrix required. This number should be a negative integer.

**filter.number**
The index of the wavelet used to compute the inner product matrix.

**family**
The family of wavelet used to compute the inner product matrix.

**tol**
In the brute force computation for Daubechies compactly supported wavelets many inner product computations are performed. This tolerance discounts any results which are smaller than tol which effectively defines how long the inner product/autocorrelation products are.

**verbose**
If TRUE then informative messages are printed. Some of these can be quite fun as the function tells you whether precomputed matrices are being used, how much computation needs to be done and so forth.

... any other arguments

Details

This function computes the inner product matrix of the discrete non-decimated autocorrelation wavelets. This matrix is used to correct the wavelet periodogram as a step to turning it into an evolutionary wavelet spectral estimate. The matrix returned by ipndacw is the one called A in the paper by Nason, von Sachs and Kroisandt.

For the Haar wavelet the matrix is computed by using the analytical formulae in the paper by Nason, von Sachs and Kroisandt and is hence very fast and efficient and can be used for large values of -J.

For other Daubechies compactly supported wavelets the matrix is computed directly by autocorrelating discrete non-decimated wavelets at different scales and then forming the inner products of these. A function that computes the autocorrelation wavelets themselves is \( \Psi_J \). This brute force computation is slow and memory inefficient hence ipndacw contains a mechanism that stores any inner product matrix that it creates according to a naming scheme defined by the convention defined in \( \text{rmname} \). The stored matrices are assigned to the user-visible environment \( \text{WTEnv} \).

These stored matrices can be used in future computations by the following automatic procedure:

1. The \( \text{rmget} \) looks to see whether previous computations have been performed that might be useful.
2. If a matrix of higher order is discovered then the appropriate top-left submatrix is returned, otherwise ...
3. If the right order of matrix is found it is returned, otherwise ...
4. If a matrix of smaller order is found it is used as the top-left submatrix of the answer. The remaining elements to the right of and below the submatrix are computed and then the whole matrix is returned, otherwise ...
5. If none are found then the whole matrix is computed in C and returned.

In this way a particular matrix for a given wavelet need only be computed once.

Value

A matrix of order \((-J) \times (-J)\) containing the inner product matrix of the discrete non-decimated autocorrelation matrices.
RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

References


See Also

ewspec, PsiJ, rmname, rmget, filter.select.

Examples

# # Let us create the 4x4 inner product matrix for the Haar wavelet. # We'll turn on the jolly verbose messages as well. #
ipndacw(-4, filter.number=1, family="DaubExPhase", verbose=TRUE) #Computing ipndacw #Calling haarmat #Took 0.0699999 seconds # # -1 -2 -3 -4 # -1 1.5000 0.7500 0.3750 0.1875 # -2 0.7500 1.7500 1.1250 0.5625 # -3 0.3750 1.1250 2.8750 2.0625 # -4 0.1875 0.5625 2.0625 5.4375 # # If we do this again it will use the precomputed version #
ipndacw(-4, filter.number=1, family="DaubExPhase", verbose=TRUE) #Computing ipndacw #Returning precomputed version: using 4 #Took 0.08 seconds # # -1 -2 -3 -4 # -1 1.5000 0.7500 0.3750 0.1875 # -2 0.7500 1.7500 1.1250 0.5625 # -3 0.3750 1.1250 2.8750 2.0625 # -4 0.1875 0.5625 2.0625 5.4375 #

# Let's use a smoother wavelet from the least-asymmetric family # and generate the 6x6 version. #
ipndacw(-6, filter.number=10, family="DaubLeAsymm", verbose=TRUE) #Computing ipndacw #Took 0.95 seconds # # -1 -2 -3 -4 -5
irregwd

Irregular wavelet transform (decomposition).

Description

This function performs the irregular wavelet transform as described in the paper by Kovac and Silverman.

Usage

irregwd(gd, filter.number=2, family="DaubExPhase", bc="periodic", verbose=FALSE)

Arguments

gd A grid structure which is the output of the makegrid function.

filter.number This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 2, the Daubechies extremal phase orthonormal compactly supported wavelet with 2 vanishing moments.

family specifies the family of wavelets that you want to use. Two popular options are "DaubExPhase" and "DaubLeAsymm" but see the help for filter.select for more possibilities.

bc specifies the boundary handling. If bc="periodic" the default, then the function you decompose is assumed to be periodic on its interval of definition, if bc="symmetric" then the function beyond its boundaries is assumed to be a symmetric reflection of the function in the boundary. The symmetric option was the implicit default in releases prior to 2.2.

verbose Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
Details

If one has irregularly spaced one-dimensional regression data \((t,y)\), say. Then the function `makegrid` interpolates this to a regular grid and then the standard wavelet transform is used to transform the interpolated data. However, unlike the standard wavelet denoising set-up the interpolated data, \(y\), values are correlated. Hence the wavelet coefficients of the interpolated will be correlated (even after using an orthogonal transform). Hence, in particular, the variance of each wavelet coefficient may well be different and so this routine also computes those variances using a fast algorithm (related to the two-dimensional wavelet transform).

When thresholding with `threshold.irregwd` the threshold function makes use of the information about the variance of each coefficient to modify the variance locally on a coefficient by coefficient basis.

Value

An object of class `irregwd` which is a list with the following components.

- **C**: Vector of sets of successively smoothed versions of the interpolated data (see description of equivalent component of `wd.object` for further information.)
- **D**: Vector of sets of wavelet coefficients of the interpolated data at different resolution levels. (see description of equivalent component of `wd.object` for further information.)
- **c**: Vector that aids in calculation of variances of wavelet coefficients (used by `threshold.irregwd`).
- **nlevelsWT**: The number of resolution levels. This depends on the length of the data vector. If \(\text{length(data)}=2^m\), then there will be \(m\) resolution levels. This means there will be \(m\) levels of wavelet coefficients (indexed \(0,1,2,...,(m-1)\)), and \(m+1\) levels of smoothed data (indexed \(0,1,2,...,m\)).
- **fl.dbase**: There is more information stored in the C and D than is described above. In the decomposition “extra” coefficients are generated that help take care of the boundary effects, this database lists where these start and finish, so the “true” data can be extracted.
- **filter**: A list containing information about the filter type: Contains the string "wavelet" or "station" depending on which type of transform was performed.
- **bc**: How the boundaries were handled.
- **date**: The date the transform was performed.

RELEASE

3.9.4 Code Copyright Arne Kovac 1997

Author(s)

Arne Kovac

See Also

`makegrid`, `wd`, `wr.wd`, `accessC`, `accessc`, `accessD`, `putD`, `putC`, `filter.select`, `plot.irregwd`, `threshold.irregwd`. 
irregwd.objects

Examples

#
# See full examples at the end of the help for makegrid.
#

irregwd.objects Irregular wavelet decomposition objects.

Description

These are objects of classes wd

They represent a decomposition of a function with respect to a wavelet basis. The function will have been interpolated to a grid and these objects represent the discrete wavelet transform wd.

Details

To retain your sanity the C and D coefficients should be extracted by the accessC and accessD functions and inserted using the putC and putD functions (or more likely, their methods), rather than by the $ operator.

One can use the accessC function to obtain the c component.

Mind you, if you want to muck about with coefficients directly, then you’ll have to do it yourself by working out what the fl.dbase list means (see first.last for a description.)

GENERATION

This class of objects is returned from the irregwd function. Some other functions that process these kinds of objects also return this class of object (such as threshold.irregwd.)

METHODS

The irregwd class of objects has methods for the following generic functions: plot, threshold,

STRUCTURE

All components in a legitimate ‘irregwd’ are identical to the components in an ordinary wd.object with the exception of type component and with the addition of the following component:

c vector that aids in the calculation of variances of wavelet coefficients (used by threshold.irregwd).

RELEASE

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Author(s)

G P Nason
See Also

`irregwd`, `threshold.irregwd`, `plot.irregwd`
IsEarly.default

Dests whether object is from an earlier version of WaveThresh

Description

Detects whether object is from an earlier version of WaveThresh.

Usage

```r
## Default S3 method:
IsEarly(x)
```

Arguments

- `x`: Object to discern

Details

The default method always returns FALSE, i.e., unless the object is of a specific type handled by a particular method then it won't be from an earlier version.

Value

Always FALSE for the generic

Author(s)

G P Nason

See Also

- `IsEarly`

IsEarly.wd

Function to detect whether a wd object is from WaveThresh2 or not

Description

Function to detect whether a wd object is from WaveThresh2 or not.

Usage

```r
## S3 method for class 'wd'
IsEarly(x)
```
Arguments

x

The wd object that you are trying to check

Details

The function merely looks to see whether the wd object has a component called date. If it does not then it is from version 2. This routine is legacy and not very important anymore.

Value

Returns TRUE if from an earlier version of WaveThresh (v2), returns FALSE if not.

Author(s)

G P Nason

See Also

IsEarly

Decides whether vector elements are integral powers of two (returns NA if not).

Description

This function checks to see whether its input is a power of two. If it is then it returns that power otherwise it returns NA.

Usage

IsPowerOfTwo(n)

Arguments

n

Vector of numbers that are to be checked whether it is a power of two.

Details

Function takes the log of the input, divides this by log(2) and if the result is integral then it knows the input is true power of two.

Value

If n is a power of two, then the power is returned otherwise NA is returned.

RELEASE

Version 3.6.0 Copyright Guy Nason 1995
**l2norm**

**Author(s)**
G P Nason

**See Also**
nlevelsWT.default.

**Examples**

```
# Try and see whether 1,2,3 or 4 are powers of two!
IsPowerOfTwo(1:4)
# [1] 0 1 NA 2
#
# Yes, 1,2 and 4 are the 0, 1 and 2nd power of 2. However, 3 is not an
# integral power of two.
```

---

**l2norm**

*Compute L2 distance between two vectors of numbers.*

**Description**

Compute L2 distance between two vectors of numbers (square root of sum of squares of differences between two vectors).

**Usage**

```
l2norm(u, v)
```

**Arguments**

- `u`: first vector of numbers
- `v`: second vector of numbers

**Details**

Function simply computes the L2 distance between two vectors and is implemented as

```
sqrt(sum((u-v)^2))
```

**Value**

A real number which is the L2 distance between two vectors.

**RELEASE**

Version 3.6 Copyright Guy Nason 1995
Note

This function would probably be more accurate if it used the Splus function vecnorm.

Author(s)

G P Nason

See Also

linfnorm, wstCV, wstCVl.

Examples

# What is the L2 norm between the following sets of vectors
#
p <- c(1,2,3,4,5)
q <- c(1,2,3,4,5)
r <- c(2,3,4,5,6)
l2norm(p,q)
# [1] 0
l2norm(q,r)
# [1] 2.236068
l2norm(r,p)
# [1] 2.236068

lennon

John Lennon image.

Description

A 256x256 matrix. Each entry of the matrix contains an image intensity value. The whole matrix represents an image of John Lennon

Usage

data(lennon)

Format

A 256x256 matrix. Each entry of the matrix contains an image intensity value. The whole matrix represents an image of John Lennon

Author(s)

G P Nason
Source

The John Lennon image was supplied uncredited on certain UNIX workstations as an examples image. I am not sure who the Copyright belongs to. Please let me know if you know.

Examples

```r
levarr(1:4, 3)
# [1] 1 3 2 4
```

Description

Subsidiary routine that generates a particular permutation

Not intended for casual user use. This function is used to provide the partition to reorder `wst.object` into `wd.object` (nondecimated time ordered) objects.

Usage

```r
levarr(v, levstodo)
```

Arguments

- `v` the vector to permute
- `levstodo` the number of levels associated with the current level in the object you wish to permute

Details

Description says all

Value

A permutation of the `v` vector according to the number of levels that need handling

Author(s)

G P Nason

See Also

`getarrvec`, `convert.wd`, `convert.wst`

Examples

```r
levarr(1:4, 3)
# [1] 1 3 2 4
```
linfnorm

Compute L infinity distance between two vectors of numbers.

Description
Compute L infinity distance between two vectors of numbers (maximum absolute difference between two vectors).

Usage
linfnorm(u, v)

Arguments
u first vector of numbers
v second vector of numbers

Details
Function simply computes the L infinity distance between two vectors and is implemented as
max(abs(u-v))

Value
A real number which is the L infinity distance between two vectors.

RELEASE
Version 3.6 Copyright Guy Nason 1995

Note
This function would probably be more accurate if it used the Splus function vecnorm.

Author(s)
G P Nason

See Also
l2norm, wstCV, wstCVl.
Examples

```r
# What is the L infinity norm between the following sets of vectors
#
p <- c(1,2,3,4,5)
q <- c(1,2,3,4,5)
r <- c(2,3,4,5,6)
linfnorm(p,q)
# [1] 0
linfnorm(q,r)
# [1] 1
linfnorm(r,p)
# [1] 1
```

---

LocalSpec  
*Compute Nason and Silverman smoothed wavelet periodogram.*

Description

This function is obsolete. Use the function `ewspec`. Performs the Nason and Silverman smoothed wavelet periodogram as described in Nason and Silverman (1995).

This function is generic.

Particular methods exist. For the wd class object this generic function uses `LocalSpec.wd`.

Usage

```r
LocalSpec(...)  
```

Arguments

```r
...  
```

See individual help pages for details.

Details

See individual method help pages for operation and examples.

Value

The LocalSpec of the wavelet object supplied. See method help files for examples.

RELEASE

Version 3.9 Copyright Guy Nason 1997

Author(s)

G P Nason
LocalSpec.wd

Compute Nason and Silverman raw or smoothed wavelet periodogram.

Description

This smoothing in this function is now obsolete. You should now use the function ewspec.

This function computes the Nason and Silverman raw or smoothed wavelet periodogram as described by Nason and Silverman (1995).

Usage

## S3 method for class 'wd'
LocalSpec(wdS, lsmooth="none", nlsmooth=FALSE, prefilter=TRUE,
verbose=FALSE, lw.number=wdS$filter$filter.number,
lw.family=wdS$filter$family, nlw.number=wdS$filter$filter.number,
nlw.family=wdS$filter$family, nlw.policy="LSuniversal",
nlw.levels=0:(nlevelsWT(wdS) - 1), nlw.type="hard", nlw.by.level=FALSE,
nlw.value=0, nlw.dev=var, nlw.boundary=FALSE, nlw.inverse=FALSE,
nlw.cvtol=0.01, nlw.Q=0.05, nlw.alpha=0.05, nlw.transform=I,
nlw.verbose=FALSE, debug.spectrum=FALSE, ...)

Arguments

Note that all options beginning "nlw" are only used if nlsmooth=T, i.e. iff NONLINEAR wavelet smoothing is used.

The stationary wavelet transform object that you want to smooth or square.

wdS
Controls the LINEAR smoothing. There are three options: "none", "Fourier" and "wavelet". They are described below. Note that Fourier begins with a capital "F".

nlsmooth
A switch to turn on (or off) the NONLINEAR wavelet shrinkage of (possibly LINEAR smoothed) local power coefficients. This option is either TRUE (to turn on the smoothing) or FALSE (to turn it off).

prefilter
If TRUE then apply a prefilter to the actual stationary wavelet coefficients at each level. This is a low-pass filter that cuts off all frequencies above the highest frequency allowed by the (Littlewood-Paley) wavelet that bandpassed the current level coefficients. If FALSE then no prefilter is applied.

verbose
If TRUE then the function chats about what it is doing. Otherwise it is silent.

lw.number
If wavelet LINEAR smoothing is used then this option controls the filter number of the wavelet within the family used to perform the LINEAR wavelet smoothing.
lw.family If wavelet LINEAR smoothing is used then this option controls the family of the wavelet used to perform the LINEAR wavelet smoothing.

nlw.number If NONLINEAR wavelet smoothing is also used then this option controls the filter number of the wavelet used to perform the wavelet shrinkage.

nlw.family If NONLINEAR wavelet smoothing is also used then this option controls the family of the wavelet used to perform the wavelet shrinkage.

nlw.policy If NONLINEAR wavelet smoothing is also used then this option controls the levels to use when performing wavelet shrinkage (see threshold.wd for different policy choices).

nlw.levels If NONLINEAR wavelet smoothing is also used then this option controls the levels to use when performing wavelet shrinkage (see threshold.wd for a detailed description of how levels can be chosen).

nlw.type If NONLINEAR wavelet smoothing is also used then this option controls the type of thresholding used in the wavelet shrinkage (either "hard" or "soft", but see threshold.wd for a list).

nlw.by.level If NONLINEAR wavelet smoothing is also used then this option controls whether level-by-level thresholding is used or if one threshold is chosen for all levels (see threshold.wd).

nlw.value If NONLINEAR wavelet smoothing is also used then this option controls if a manual (or similar) policy is supplied to nlw.policy then the nlw.value option carries the manual threshold value (see threshold.wd).

nlw.dev If NONLINEAR wavelet smoothing is also used then this option controls the type of variance estimator that is used in wavelet shrinkages (see threshold.wd). One possibility is the Splus var() function, another is the WaveThresh function madmad().

nlw.boundary If NONLINEAR wavelet smoothing is also used then this option controls whether boundary coefficients are also thresholded (see threshold.wd).

nlw.verbose If NONLINEAR wavelet smoothing is also used then this option controls whether the threshold function prints out messages as it thresholds levels (see threshold.wd).

nlw.cvtol If NONLINEAR wavelet smoothing is also used then this option controls the optimization tolerance is cross-validation wavelet shrinkage is used (see threshold.wd).

nlw.Q If NONLINEAR wavelet smoothing is also used then this option controls the Q value for wavelet shrinkage (see threshold.wd).

nlw.alpha If NONLINEAR wavelet smoothing is also used then this option controls the alpha value for wavelet shrinkage (see threshold.wd).

nlw.transform If NONLINEAR wavelet smoothing is also used then this option controls a transformation that is applied to the squared (and possibly linear smoothed) stationary wavelet coefficients before shrinkage. So, for examples, you might want to set nlw.transform=log to perform wavelet shrinkage on the logs of the squared (and possibly linear smoothed) stationary wavelet coefficients.

nlw.inverse If NONLINEAR wavelet smoothing is also used then this option controls the inverse transformation that is applied to the wavelet shrunk coefficients before they are put back into the stationary wavelet transform structure. So, for examples, if the nlw.transform is log() you should set the inverse to nlw.inverse=exp.
If this option is \( T \) then spectrum plots are produced at each stage of the squaring/smoothing. Therefore if you put in the non-decimated wavelet transform of white noise you can get a fair idea of how the coefficients are filtered at each stage.

... any other arguments

**Details**

*This smoothing in this function is now obsolete.* Use the function `ewspec` instead. However, this function is still useful for computing the raw periodogram.

This function attempts to produce a picture of local time-scale power of a signal. There are two main components to this function: linear smoothing of squared coefficients and non-linear smoothing of these. Neither, either or both of these components may be used to process the data. The function expects a non-decimated wavelet transform object (of class `wd`, type="station") such as that produced by the `wd()` function with the type option set to "station". The following paragraphs describe the various methods of smoothing.

**LINEAR SMOOTHING.** There are three varieties of linear smoothing. None simply squares the coefficients. Fourier and wavelet apply linear smoothing methods in accordance to the prescription given in Nason and Silverman (1995). Each level in the SWT corresponds to a band-pass filtering to a frequency range \([sl, sh]\). After squaring we obtain power in the range \([0, 2sl]\) and \([2sl, 2sh]\). The linear smoothing gets rid of the power in \([2sl, 2sh]\). The Fourier method simply applies a discrete Fourier transform (rfft) and cuts off frequencies above \(2sl\). The wavelet method is a bit more subtle. The DISCRETE wavelet transform is taken of a level \((i)\) and all levels within the DWT, \(j\), where \(j>i\) are set to zero and then the inverse is taken. Approximately this performs the same operation as the Fourier method only faster. By default the same wavelets are used to perform the linear smoothing as were used to compute the stationary wavelet transform in the first place. This can be changed by altering `lw.number` and `lw.family`.

**NONLINEAR SMOOTHING.** After either of the linear smoothing options above it is possible to use wavelet shrinkage upon each level in the squared (and possibly Fourier or wavelet linear smoothed) to denoise the coefficients. This process is akin to smoothing the ordinary periodogram. All the usual wavelet shrinkage options are available as `nlw.*` where `*` is one of the usual `threshold.wd` options. By default the same wavelets are used to perform the wavelet shrinkage as were used to compute the non-decimated wavelet transform. These wavelets can be replaced by altering `nlw.number` and `nlw.family`. Also, it is possible to transform the squared (and possibly smoothed coefficients) before applying wavelet shrinkage. The transformation is effected by supplying an appropriate transformation function (AND ITS INVERSE) to `nlw.transform` and `nlw.inverse`. (For examples, `nlw.transform=log` and `nlw.inverse=exp` might be a good idea).

**Value**

An object of class `wd` a time-ordered non-decimated wavelet transform. Each level of the returned object contains a smoothed wavelet periodogram. Note that this is not the corrected smoothed wavelet periodogram, or the *evolutionary wavelet spectrum*. Use the function `ewspec` to compute the evolutionary wavelet spectrum.

**RELEASE**

Version 3.9 Copyright Guy Nason 1998
**Author(s)**

G P Nason

**References**


**See Also**

ewspect.

**Examples**

```r
# This function is obsolete. See ewspec()
#
# Compute the raw periodogram of the BabyECG
# data using the Daubechies least-asymmetric wavelet N=10.
#
data(BabyECG)
babywdS <- wd(BabyECG, filter.number=10, family="DaubLeAsymm", type="station")
babyWP <- LocalSpec(babywdS, lsmooth = "none", nlsmooth = FALSE)
## Not run: plot(babyWP, main="Raw Wavelet Periodogram of Baby ECG")
#
# Note that the lower levels of this plot are too large. This is partly because
# there are "too many" coefficients at the lower levels. For a better
# picture of the local spectral properties of this time series see
# the examples section of ewspec
#
# Other results of this function can be seen in the paper by
#
```

---

**Description**

This function computes a local spectra as described in Nason and Silverman (1995). However, the function is obsolete and superceded by `ewspect`.

**Usage**

```r
## S3 method for class 'wst'
LocalSpec(wst, ...)
```

**Arguments**

- `wst` The wst object to perform local spectral analysis on
- `...` Other arguments to `LocalSpec.wd`. 
Details
   Description says it all.
   However, this function converts the `wst.object` object to a nondecimated `wd.object` and then calls `LocalSpec.wd`.

Value
   Same value as `LocalSpec.wd`.

Author(s)
   G P Nason

See Also
   `ewspect`

---

**logabs**  
Take the logarithm of the squares of the argument

Description
   Take the log of the squares of the argument

Usage
   logabs(x)

Arguments
   x  A number

Details
   Description says all

Value
   Just the logarithm of the square of the argument

Author(s)
   G P Nason

See Also
   `image.wd`, `image.wst`
**LSWsim**  
*Simulate arbitrary locally stationary wavelet process.*

**Examples**

```r
logabs(3)  
# [1] 1.098612
```

**Description**

Simulates an arbitrary LSW process given a spectrum.

**Usage**

```r
LSWsim(spec)
```

**Arguments**

- `spec` An object of class `wd` (the NDWT kind) which contains the spectral information for simulating your process. See examples below on how to create and manipulate this object.

**Details**

This function uses a spectral definition in `spec` to simulate a locally stationary wavelet process (defined by the Nason, von Sachs and Kroisandt, 2000, JRSSB paper).

The input object, `spec`, is a `wd` class object which contains a spectral description. In particular, all coefficients must be nonnegative and `LSWsim()` checks for this and returns an error if it is not so. Other than that the spectrum can contain pretty much anything. An object of this type can be easily created by the convenience routine `cns`. This creates an object of the correct structure but all elements are initially set to zero. The spectrum structure `spec` can then be filled by using the `putD` function.

The function works by first checking for non-negativity. Then it takes the square root of all coefficients. Then it multiplies all coefficients by a standard normal variate (from `rnorm()` and multiples the finest level by 2, the next finest by 4, the next by 8 and so on. (This last scalar multiplication is intended to undo the effect of the average basis averaging which combines coefficients but divides by two at each combination). Finally, the modified spectral object is subjected to the `convert` function which converts the object from a `wd` time-ordered NWDT object to a `wst` packet-ordered object which can then be inverted using `AvBasis`.

Note that the NDWT transforms in WaveThresh are periodic so that the process that one simulates with this function is also periodic.

**Value**

A vector simulated from the spectral description given in the `spec` description. The returned vector will exhibit the spectral characteristics defined by `spec`.
RELEASE

Version 3.9 Copyright Guy Nason 2004

Author(s)

G P Nason

See Also

wd.object, putD, cns, AvBasis, convert, ewspec, plot.wst.

Examples

# Suppose we want to create a LSW process of length 1024 and with a spectral
# structure that has a squared sinusoidal character at level 4 and a burst of
# activity from time 800 for 100 observations at scale 9 (remember for a
# process of length 1024 there will be 9 resolution levels (since 2^10=1024)
# where level 9 is the finest and level 0 is the coarsest).
#
# First we will create an empty spectral structure for series of 1024 observations
#
#
# mystep <- cns(1024)
#
# If you plot it you'll get a null spectrum (since every spectral entry is zero)
#
## Not run: plot(mystep, main="My Spectrum")
#
# Now let's add the desired spectral structure
#
# First the squared sine (remember spectra are positive)
#
mystep <- putD(mystep, level=4, sin(seq(from=0, to=4*pi, length=1024))^2)
#
# Let's create a burst of spectral info of size 1 from 800 to 900. Remember
# the whole vector has to be of length 1024.
#
burstat800 <- c(rep(0,800), rep(1,100), rep(0,124))
#
# Insert this (00000111000) type vector into the spectrum at fine level 9
#
mystep <- putD(mystep, level=9, v=burstat800)
#
# Now it's worth plotting this spectrum
#
## Not run: plot(mystep, main="My Spectrum")
#
# The squared sinusoid at level 4 and the burst at level 9 can clearly
# be seen
#
#
# Now simulate a random process with this spectral structure.
myLSWproc <- LSWsim(myspec)
# Let's see what it looks like
## Not run: ts.plot(myLSWproc)
# The burst is very clear but the sinusoidal structure is less apparent.
# That's basically it.
# You could now play with the spectrum (ie alter it) or simulate another process
# from it.
# [The following is somewhat of an aside but useful to those more interested
# in the LSW scene. We could now ask, so what? So you can simulate an
# LSW process. How can I be sure that it is doing so correctly? Well, here is
# a partial, computational, answer. If you simulate many realisations from the
# same spectral structure, estimate its spectrum, and then average those
# estimates then the average should tend to the spectrum you supplied. Here is a
# little function to do this (just for Haar but this function could easily be
# developed to be more general):
checkmyews <- function(spec, nsim=10){
  ans <- cns(2^nlevelsWT(spec))
  for(i in 1:nsim) {
    cat(".")
    LSWproc <- LSWsim(spec)
    ews <- ewspec(LSWproc, filter.number=1, family="DaubExPhase",
                WPsmooth=F)
    ans$D <- ans$D + ews$S$D
    ans$C <- ans$C + ews$S$C
  }
  ans$D <- ans$D/nsim
  ans$C <- ans$C/nsim
  ans
}
# If you supply it with a spectral structure (like myspec)
# from above and do enough simulations you'll get something looking like
# the original myspec structure. E.g. try
## Not run: plot(checkmyews(myspec, nsim=100))
## for fun. This type of check also gives you some idea of how much data
# you really need for LSW estimation for given spectral structures.]

lt.to.name  Convert desired level and orientation into code used by imwd
**Description**

Function codes the name of a desired level and wavelet coefficient orientation into a string which is used by the 2D DWT functions to access and manipulate wavelet coefficients.

**Usage**

lt.to.name(level, type)

**Arguments**

- **level**: Resolution level of coefficients that you want to extract or manipulate.
- **type**: One of CC, CD, DC or DD indicating smoothed, horizontal, vertical or diagonal coefficients

**Details**

For the 1D wavelet transform (and others) the `accessC` and `accessD` function extracts wavelet coefficients from 1D wavelet decomposition objects. For `imwd.object` class objects, which are the 2D wavelet transforms of lattice objects (images) the wavelet coefficients are stored within components of the list object that underlies the imwd object.

This function provides an easy way to specify a resolution level and orientation in a human readable way and this function then produces the character string necessary to access the wavelet coefficients in an imwd object.

Note that this function does not actually extract any coefficients itself.

**Value**

A character string which codes the level and type of coefficients. It reads wXLY X is the resolution level and Y is an integer corresponding to the orientation (1=horizontal, 2=vertical, 3=diagonal, 4=smoothed).

**Author(s)**

G P Nason

**See Also**

`imwd`, `imwd.object`

**Examples**

```r
# Generate the character string for the component of the imwd object
# The string associated with the diagonal detail at the third level...
#
lt.to.name(3, "DD")
# [1] "w3L3"
#```
## madmad

Show how to access wavelet coefficients of imwd object.

First, make up some data (using matrix/rnorm) and then subject it to an image wavelet transform.

```r
tmpimwd <- imwd(matrix(rnorm(64),64,64))
```

Get the horizontal coefficients at the 2nd level

```r
tmpimwd[[lt.to.name(2, "CD")]]
```

If you want the coefficients returned as a matrix use the matrix function, i.e.

```r
matrix(tmpimwd[[lt.to.name(2, "CD")]], 4,4)
```

Note that the dimensions of the matrix depend on the resolution level that you extract and dim = 2^level

---

### madmad

**Compute square of median absolute deviation (mad) function.**

#### Description

This function simply returns the square of the median absolute deviation (mad) function in S-Plus. This is required for supply to the `threshold` series of functions which require estimates of spread on the variance scale (not the standard deviation scale).

#### Usage

```r
madmad(x)
```

#### Arguments

- `x` The vector for which you wish to compute the square of mad on.

#### Value

The square of the median absolute deviation of the coefficients supplied by `x`.
RELEASE

Version 3.4.1 Copyright Guy Nason 1994

Note

It’s a MAD MAD world!

Author(s)

G P Nason

See Also

threshold

Examples

#
#
# Generate some normal data with mean 0 and sd of 8
# and we’ll also contaminate it with an outlier of 1000000
# This is akin to signal wavelet coefficients mixing with the noise.
#
ContamNormalData <- c(1000000, rnorm(1000, mean=0, sd=8))
#
# What is the variance of the data?
#
var(ContamNormalData)
# [1] 999000792
#
# Wow, a seriously unrobust answer!
#
# How about the median absolute deviation?
#
mad(ContamNormalData)
# [1] 8.14832
#
# A much better answer!
#
# Now let’s use madmad to get the answer on the variance scale
#
madmad(ContamNormalData)
# [1] 66.39512
#
# The true variance was 64, so the 66.39512 was a much better answer
# than that returned by the call to the variance function.
**Description**

Computes the values which specify the covariance structure of complex-valued wavelet coefficients.

**Usage**

```r
make.dwt(nlevels, filter.number = 3.1, family = "LinaMayrand")
```

**Arguments**

- `nlevels`: The number of levels of the wavelet decomposition.
- `filter.number`, `family`: Specifies the wavelet used; see `filter.select` for more details.

**Details**

If real-valued signals are decomposed by a discrete wavelet transform using a complex-valued Daubechies wavelet (as described by Lina & Mayrand (1995)), the resulting coefficients are complex-valued. The covariance structure of these coefficients are determined by the diagonal entries of the matrix $WW^T$. This function computes these values for use in shrinkage. For more details, see Barber & Nason (2004)

**Value**

A vector giving the diagonal elements of $WW^T$.

**RELEASE**

Part of the CThresh addon to WaveThresh. Copyright Stuart Barber and Guy Nason 2004.

**Author(s)**

Stuart Barber

**See Also**

- `cthresh`
**makegrid**

Interpolate data to a grid.

**Description**

This function takes a set of univariate (x,y) data with x arbitrary in (0,1) and linearly interpolates (x,y) to an equally spaced dyadic grid.

**Usage**

```
makegrid(t, y, gridn = 2^(floor(log(length(t)-1,2)) + 1))
```

**Arguments**

- **t**: A vector of x data. Each of the entries of x must lie between 0 and 1.
- **y**: A vector of y data. Each entry of y corresponds to the same-positioned entry in x and so y must be of the same length as x.
- **gridn**: The number of grid points in the dyadic grid that the (x,y) gets interpolated to. By default this is the next power of two larger than the length of x.

**Details**

One method for performing wavelet regression on data that is not equally spaced nor of power of two length is that described in Kovac, (1997) and Kovac and Silverman, (2000).

The Kovac-Silverman algorithm linearly interpolates arbitrarily spaced (x,y) data to a dyadic grid and applies wavelet shrinkage to the interpolated data. However, if one assumes that the original data obeys a signal+noise model with iid data the interpolated data will be correlated due to the interpolation. This fact needs to be taken into account after taking the DWT and before thresholding one realizes that each coefficient has its own variance. The Kovac-Silverman algorithm computes this variance efficiently using knowledge of the interpolation scheme.

**Value**

An object of class griddata.

**RELEASE**

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**Author(s)**

Arne Kovac

**See Also**

accessc, irregwd, newsure, plot.irregwd, threshold.irregwd,
Examples

```r
# Generate some values in (0,1), then sort them (for plotting)
#
# tt <- sort(runif(100))
#
# Now evaluate the \code{\link{doppler}} function and add
# some noise.
#
# yy <- doppler(tt) + rnorm(100, 0, 0.15)
#
# Now make the grid with this data
#
# yygrid <- makegrid(t=tt, y=yy)
#
# Jolly good. Now let's take the wavelet transform of this gridded data.
# Note that we have to use the \code{\link{irregwd}} function
# of the gridded data as it computes the variances of the coefficients
# as well as the coefficients themselves.
#
# yyirregwd <- irregwd(yygrid)
#
# You might want to plot the coefficients
#
# If you want to see the actual coefficients you have to first convert
# the class of the yyirregwd object to a wd object and then use
# \code{\link{plot.wd}} like this
#
# yyirregwd2 <- yyirregwd
# class(yyirregwd2) <- "wd"
## Not run: plot(yyirregwd2)
#
# If you want to see the variance factors (essentially the coefficient
# variances divided by the overall variance). Then just use
# \code{\link{plot.irregwd}}
#
# ## Not run: plot(yyirregwd)
#
# Ok. So you've seen the coefficients. Now let's do some thresholding.
#
# yy.thresh.sure <- threshold(yyirregwd, policy="sure", type="soft", dev=madmad)
#
# And now do the reconstruct
#
# yy.wr <- wr(yy.thresh.sure)
#
# And you can even plot the answer on the new grid!
## Not run: plot(yygrid$gridt, yy.wr, type="l")
#
# And superimpose the original data!
#```

## Not run: points(tt, yy)
#
# This is sort of \code{Doppler} like!

makewpstDO  

### Description

Takes two time series: one a real-valued discrete-time time series, timeseries, the other, groups, a time series containing factor levels. This function performs a discriminant analysis of groups on a subset of the best-correlating nondecimated wavelet packets of timeseries.

### Usage

```r
makewpstDO(timeseries, groups, filter.number=10, family="DaubExPhase", mincor=0.69999999999999996)
```

### Arguments

- **timeseries**: The time series which is the ‘dependent variable’, ie discrimination will be performed on the variables extracted from the non-decimated wavelet packet transform of this time series.
- **groups**: The factor levels as a time series.
- **filter.number**: The smoothness of the wavelet involved in the nondecimated wavelet packet transform. See `filter.select`.
- **family**: The wavelet family, see `filter.select`.
- **mincor**: Variables from the nondecimated wavelet packet transform with correlations less than this argument will be discarded in the first pass, and not considered as possible useful discriminants.

### Details

This function implements the ‘discrimination’ version of the "Wavelet packet transfer function modelling of nonstationary series" by Guy Nason and Theofanis Sapatinas, *Statistics and Computing*, 12, 45-56.

The function first takes the non-decimated wavelet packet transform of timeseries using the `wpst` function. Then the set of nondecimated wavelet packets is put into matrix form using the `wpst2discr` function. The `Best1DCols` function selects those variables from the matrix whose correlation with the groups time series is greater than `mincor`. The selected variables are put into a reduced matrix.

The next step, `BMdiscr`, performs a linear discriminant analysis of the groups values onto the reduced matrix. In principle, one could have carried out a discriminant analysis using the full matrix of all the packets, but the problem is not well-conditioned and computationally efficient. The strategy adopted by Nason and Sapatinas is to do a "first pass" to select a large number of "likely" variables that might contribute something to discrimination, and then carry out a "second..."
pass" which performs a more detailed analysis to jointly determine which variables are the key ones for discrimination.

Note, using the discriminant model developed here, it is possible to use future values of timeseries and the model to predict future values of groups. See example below.

Value

An object of class wpstDO. This is a list containing the following components.

BPd Object returned from the BMdiscr function. Contains the reduced matrix and the discriminant object
BP Object returned from the Best1DCols function, essentially the reduced matrix and the groups variable.
filter The details of the wavelet filter used. This is used if the other components are used to perform discrimination on new data one needs to know what wavelet was used to perform the original nondecimated wavelet packet transform.

Author(s)

G P Nason

See Also

basisplot.BP, Best1DCols, BMdiscr, wpst, wpst2discr, wpstCLASS

Examples

# Use BabySS and BabyECG data for this example.
# Want to predict future values of BabySS from future values of BabyECG
# Build model on first 256 values of both
data(BabyECG)
data(BabySS)
BabyModel <- makewpstDO(timeseries=BabyECG[1:256], groups=BabySS[1:256], mincor=0.5)
# The results (ie print out answer)
BabyModel
#Stationary wavelet packet discrimination object
#Composite object containing components:
#Fisher's discrimination: done
#BP component has the following information
#BP class object. Contains "best basis" information
#Components of object:
#[6] "groups"
#Number of levels 8
#List of "best" packets
#Level id Packet id Basis coef
# You can plot the select basis graphically using

```r
## Not run: basisplot(BabyModel$BP)
```

# An interesting thing are the final "best" packets, these form the # "reduced" matrix, and the final discrimination is done on this # In this case 7 wavelet packets were identified as being good for # univariate high correlation.

# In the second pass lda analysis, using the reduced matrix, the following # turns up as the best linear discriminant vectors

# The discriminant variables can be obtained by typing

```r
Babymodel$BPd$dm$scaling
```

<table>
<thead>
<tr>
<th></th>
<th>LD1</th>
<th>LD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1,]</td>
<td>5.17130434</td>
<td>1.8961807</td>
</tr>
<tr>
<td>[2,]</td>
<td>1.56487144</td>
<td>-3.5025251</td>
</tr>
<tr>
<td>[3,]</td>
<td>1.69328553</td>
<td>1.1585477</td>
</tr>
<tr>
<td>[4,]</td>
<td>3.63362324</td>
<td>8.4543247</td>
</tr>
<tr>
<td>[5,]</td>
<td>0.15202947</td>
<td>-0.4530523</td>
</tr>
<tr>
<td>[6,]</td>
<td>0.35659009</td>
<td>-0.3850318</td>
</tr>
<tr>
<td>[7,]</td>
<td>0.09429836</td>
<td>-0.1281240</td>
</tr>
</tbody>
</table>

# Now, suppose we get some new data for the BabyECG time series.

# For the purposes of this example, this is just the continuing example # ie BabyECG[257:512]. We can use our new discriminant model to predict # new values of BabySS

```r
BabySSpred <- wpstCLASS(newTS=BabyECG[257:512], BabyModel)
```

# Let's look at the first 10 (eg) values of this prediction

```r
BabySSpred$class[1:10]
```

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[1,]</td>
</tr>
</tbody>
</table>

# Good. Now let's look at what the "truth" was:

```r
BabySS[257:267]
```

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[1,]</td>
</tr>
</tbody>
</table>

# Good. However, the don't agree everywhere, let's do a cross classification # between the prediction and the truth.

```r
> table(tmp2$class, BabySS[257:512])
```

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
makewpstRO

Make a wavelet packet regression object from a dependent and independent time series variable.

Description

The idea here is to try and build facilities to enable a transfer function model along the lines of that described by Nason and Sapatinas 2002 in *Statistics and Computing*. The idea is to turn the timeseries variable into a set of nondecimated wavelet packets which are already pre-selected to have some semblance of relationship to the response time series. The function does not actually perform any regression, in contrast to the related `makewpstDO` but returns a data frame which the user can use to build their own models.

Usage

```r
makewpstRO(timeseries, response, filter.number = 10, 
            family = "DaubExPhase", trans = logabs, percentage = 10)
```

Arguments

- **timeseries**: The dependent variable time series. This series is decomposed using the `wpst` function into nondecimated wavelet packets, need to be a power of two length.
- **response**: The independent or response time series.
- **filter.number**: The type of wavelet used within `family`, see `filter.select`.
- **family**: The family of wavelet, see `filter.select`.
- **trans**: A transform to apply to the nondecimated wavelet packet coefficients before any selection.
- **percentage**: The top percentage of nondecimated wavelet packets that correlated best with the response series will be preselected.

Details

The idea behind this methodology is that a response time series might not be directly related to the dependent timeseries time series, but it might be related to the nondecimated wavelet packets of the timeseries, these packets can pick out various features of the timeseries including certain delays, oscillations and others.

The best packets (the number if controlled by `percentage`), those that correlate best with `response` are selected and returned. The `response` and the best nondecimated wavelet packets are returned in a data frame object and then any convenient form of statistical modeling can be used to build a model of the `response` in terms of the packet variables.
Once a model has been built it can be interpreted in the usual way, but with respect to nondecimated wavelet packets.

Note that nondecimated wavelet packets are essential, as they are all of the same length as the original response series. If a decimated wavelet packet algorithm had been used then it is not clear what to do with the "gaps"!

If new timeseries data comes along the \texttt{wpstREGR} function can be used to extract the identical packets as the ones produced by this function (as the result of this function stores the identities of these packets). Then the statistical modelling that build the model from the output of this function, can be used to predict future values of the response time series from future values of the timeseries series.

### Value

An object of class \texttt{wpstRO} containing the following items

- \texttt{df}: A data frame containing the response time series and a number of columns/variables/packets that correlated with response series. These are all entitled "Xn" where n is some integer

- \texttt{ixvec}: A packet index vector. After taking the nondecimated wavelet packet transform, all the packets are stored in a matrix. This vector indicates those that were preselected

- \texttt{level}: The original level from which the preselected vectors came from

- \texttt{pktix}: Another index vector, this time referring to the original wavelet packet object, not the matrix in which they subsequently got stored

- \texttt{nlevelsWT}: The number of resolution levels in the original wavelet packet object

- \texttt{cv}: The correlation vector. These are the values of the correlations of the packets with the response, then sorted in terms of decreasing absolute correlation

- \texttt{filter}: The wavelet filter details

- \texttt{trans}: The transformation function actually used

### Author(s)

G P Nason

### References


### See Also

\texttt{makewpstDO, wpst, wpstREGR}
Examples

data(BabyECG)
baseseries <- BabyECG[1:256]
#
# Make up a FICTITIOUS response series!
#
response <- BabyECG[6:261]*3+52
#
# Do the modeling
#
BabeModel <- makewpstRO(timeseries=baseseries, response=response)

#Level: 0 ..........
#1 ..........
#2 ..........
#3 ..........
#4 ..........
#5
#6
#7
#
#Contains SWP coefficients
#Original time series length: 256
#Number of bases: 25
#Some basis selection performed
#  Level Pkt Index Orig Index Score
#[1,] 5 0 497 0.6729833
#[2,] 4 0 481 0.6120771
#[3,] 6 0 505 0.4550616
#[4,] 3 0 449 0.4309924
#[5,] 7 0 509 0.3779385
#[6,] 1 53 310 0.3275428
#[7,] 2 32 417 -0.3274858
#[8,] 2 59 444 -0.2912863
#[9,] 3 16 465 -0.2649679
# [10,] 1 110 367 0.2605178
# etc. etc.
#
# Let's look at the data frame component
#
names(BabeModel$df)
#[1] "response" "X1"  "X2"  "X3"  "X4"  "X5"
#[7] "X6"  "X7"  "X8"  "X9"  "X10" "X11"
#[13] "X12" "X13" "X14" "X15" "X16" "X17"
#[19] "X18" "X19" "X20" "X21" "X22" "X23"
#[25] "X24" "X25"
#
# Generate a formula including all of the X's (note we could use the .
# argument, but we later want to be more flexible
#
xnam <- paste("X", 1:25, sep="")
flma1 <- as.formula(paste("response ~ ", paste(xnam, collapse = "+")))
# Now let's fit a linear model, the response on all the Xs
Babe.lm1 <- lm(fmla1, data=BabeModel$df)
#
# Do an ANOVA to see what's what
#
anova(Babe.lm1)

#Analysis of Variance Table
#
#Response: response
#
# Df Sum Sq Mean Sq F value Pr(>F)
#X1 1 214356 214356 265.7656 < 2.2e-16 ***
#X2 1 21188 21188 26.2701 6.289e-07 ***
#X3 1 30534 30534 3.347e-09 ***
#X4 1 312 312 0.3871 0.5344439
#X5 1 9275 9275 11.4999 0.0008191 ***
#X6 1 35 35 0.0439 0.8343135
#X7 1 195 195 0.2417 0.6234435
#X8 1 94 94 0.1171 0.7324600
#X9 1 331 331 0.4103 0.5224746
#X10 1 0 0 0.0006 0.9810560
#X11 1 722 722 0.8952 0.3450597
#X12 1 0 0 0.0004 0.9850243
#X13 1 77 77 0.0959 0.758769
#X14 1 2770 2770 3.4342 0.0651404 .
#X15 1 6 6 0.0072 0.9326155
#X16 1 389 389 0.4821 0.4881649
#X17 1 44 44 0.0544 0.8157015
#X18 1 44 44 0.0547 0.8152640
#X19 1 4639 4639 5.7518 0.0172702 *
#X20 1 490 490 0.6077 0.4364469
#X21 1 389 389 0.4823 0.4888660
#X22 1 85 85 0.1048 0.7463860
#X23 1 1710 1710 2.1198 0.1467664
#X24 1 12 12 0.0148 0.9033427
#X25 1 82 82 0.1019 0.7498804
#Residuals 230 185509 807

#Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
#
# Looks like X1, X2, X3, X5, X14 and X19 are "significant". Also throw in X4 as it was a highly ranked preselected variable, and refit
#
fmla2 <- response ~ X1 + X2 + X3 + X4 + X5 + X14 + X19
Babe.lm2 <- lm(fmla2, data=BabeModel$df)
#
# Let's see the ANOVA table for this
#
anova(Babe.lm2)

#Analysis of Variance Table
#
#Response: response
```r
# Df Sum Sq Mean Sq  F value Pr(>F)
# X1  1   214356  214356 279.807 3 < 2e-16 ***
# X2  1    21188   21188  27.658  3.128e-07 ***
# X3  1    30534   30534  39.856  1.252e-09 ***
# X4  1     312     312  0.407  0.5238034
# X5  1    9275    9275  12.108  0.0005931 ***
# X14 1    3095    3095   4.041  0.0455030 *
# X19 1    4540    4540  5.926  0.0156263 *
# Residuals 248  189989    766
#---
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# So let's drop X4, refit, and then do ANOVA

Babe.lm3 <- update(Babe.lm2, . ~ . -X4)
anova(Babe.lm3)

# After viewing this, drop X14

Babe.lm4 <- update(Babe.lm3, . ~ . -X14)
anova(Babe.lm4)

# Let's plot the original series, and the "fitted" one

## Not run: ts.plot(BabeModel$df[["response"]])
## Not run: lines(fitted(Babe.lm4), col=2)

# Let's plot the wavelet packet basis functions associated with the model

## Not run: oldpar <- par(mfrow=c(2,2))
## Not run: z <- rep(0, 256)
## Not run: zwp <- wp(z, filter.number=BabeModel$filter$filter.number,
## Not run: family=BabeModel$filter$family)
## End(Not run)
## Not run: draw(zwp, level=BabeModel$level[1], index=BabeModel$pktix[1], main="", sub="")
## Not run: draw(zwp, level=BabeModel$level[2], index=BabeModel$pktix[2], main="", sub="")
## Not run: draw(zwp, level=BabeModel$level[3], index=BabeModel$pktix[3], main="", sub="")
## Not run: draw(zwp, level=BabeModel$level[5], index=BabeModel$pktix[5], main="", sub="")
## Not run: par(oldpar)

# Now let's do some prediction of future values of the response, given
# future values of the baseseries

newseries <- BabyECG[257:512]

# Get the new data frame

newdfinfo <- wpstREGR(newTS = newseries, wpstRO=BabeModel)

# Now use the best model (Babe.lm4) with the new data frame (newdfinfo)
# to predict new values of response

newresponse <- predict(object=Babe.lm4, newdata=newdfinfo)
```
# What is the “true” response, well we made up a response earlier, so let's
# construct the true response for this future data (in your case you’ll
# have a separate genuine response variable)
#
# trucfictresponse <- BabyECG[262:517]*3+52
#
# Let's see them plotted on the same plot
## Not run: ts.plot(trucfictresponse)
## Not run: lines(newresponse, col=2)
#
# On my plot they look tolerably close!
#

MaNoVe

Make Node Vector (using Coifman-Wickerhauser best-basis type algorithm)

Description

This generic function chooses a “best-basis” using the Coifman-Wickerhauser (1992) algorithm. This function is generic. Particular methods exist: MaNoVe.wp and MaNoVe.wst.

Usage

MaNoVe(...)

Arguments

... Methods may have other arguments

Details

Description says all.

Value

A node vector, which describes a particular basis specification relevant to the kind of object that the function was applied to.

Author(s)

G P Nason

See Also

MaNoVe.wp, MaNoVe.wst, wp.object, wst.object, wp, wst
MaNoVe/wp

**Make Node Vector (using Coifman-Wickerhauser best-basis type algorithm) on wavelet packet object**

**Description**

This method chooses a "best-basis" using the Coifman-Wickerhauser (1992) algorithm applied to wavelet packet, `wp.object`, objects.

**Usage**

```r
## S3 method for class 'wp'
MaNoVe(wp, verbose=FALSE, ...)
```

**Arguments**

- `wp` The `wp` object for which you wish to find the best basis for.
- `verbose` Whether or not to print out informative messages
- `...` Other arguments

**Details**

Description says all.

**Value**

A wavelet packet node vector object of class `nvwp`, a basis description. This can be fed into a basis inversion using, say, the function `InvBasis`.

**Author(s)**

G P Nason

**See Also**

`InvBasis`, `MaNoVe`, `MaNoVe.wst`, `wp.object.wp`

**Examples**

```r
# See example of use of this function in the examples section
# of the help of plot.wp
#
# A node vector vnv is created there that gets plotted.
#```
Description

This method chooses a "best-basis" using the Coifman-Wickerhauser (1992) algorithm applied to nondecimated wavelet transform, `wst.object`, objects.

Usage

```r
## S3 method for class 'wst'
MaNoVe(wst, entropy=Shannon.entropy, verbose=FALSE, stopper=FALSE, alg="C", ...)
```

Arguments

- `wst`: The wst object for which you wish to find the best basis for.
- `entropy`: The function used for computing the entropy of a vector
- `verbose`: Whether or not to print out informative messages
- `stopper`: Whether the computations are temporarily stopped after each packet. This can be useful in conjunction with the `verbose` argument so as to see computations proceed one packet at a time.
- `alg`: If "C" then fast compiled C code is used (in which case the entropy function is ignored and the C code uses an internal Shannon entropy. Otherwise, slower R code is used but an arbitrary entropy argument can be used
- `...`: Other arguments

Details

Description says all

Value

A wavelet node vector object, of class `nv`, a basis description. This can be fed into a basis inversion using, say, the function `InvBasis`.

Author(s)

G P Nason

See Also

- `InvBasis`, `MaNoVe`, `MaNoVe.wp`, `Shannon.entropy`, `wst.object`, `wst`
Examples

# What follows is a simulated denoising example. We first create our
# "true" underlying signal, v. Then we add some noise to it with a signal
# to noise ratio of 6. Then we take the packet-ordered non-decimated wavelet
# transform and then threshold that.
#
# Then, to illustrate this function, we compute a "best-basis" node vector
# and use that to invert the packet-ordered NDWT using this basis. As a
# comparison we also use the Average Basis method
# (cf Coifman and Donoho, 1995).
#
# NOTE: It is IMPORTANT to note that this example DOES not necessarily
# use an appropriate or good threshold or necessarily the right underlying
# wavelet. I am trying to show the general idea and please do not "quote" this
# example in literature saying that this is the way that WaveThresh (or
# any of the associated authors whose methods it attempts to implement)
# does it. Proper denoising requires a lot of care and thought.
#
# Here we go....
#
# Create an example vector (the Donoho and Johnstone heavisine function)
# v <- DJ.EX()$heavi
# Add some noise with a SNR of 6
# vnoise <- v + rnorm(length(v), 0, sd=sqrt(var(v))/6)
# Take packet-ordered non-decimated wavelet transform (note default wavelet
# used which might not be the best option for denoising performance).
# vnwst <- wst(vnoise)
# Let's take a look at the wavelet coefficients of vnoise
# ## Not run: plot(vnwst)
#
# Wow! A huge number of coefficients, but mostly all noise.
#
# Threshold the resultant NDWT object.
# (Once again default arguments are used which are certainly not optimal).
# vnwstT <- threshold(vnwst)
#
# Let's have a look at the thresholded wavelet coefficients
# ## Not run: plot(vnwstT)
# Ok, a lot of the coefficients have been removed as one would expect with
# universal thresholding
#
# Now select packets for a basis using a Coifman-Wickerhauser algorithm
#
# vnnv <- MaNoVe(vnwstT)
#
# Let's have a look at which packets got selected
#
# vnnv
# Level :  9 Action is R (getpacket Index:  1 )
# Level :  8 Action is L (getpacket Index:  2 )
# Level :  7 Action is L (getpacket Index:  4 )
# Level :  6 Action is L (getpacket Index:  8 )
# Level :  5 Action is R (getpacket Index: 17 )
# Level :  4 Action is L (getpacket Index: 34 )
# Level :  3 Action is L (getpacket Index: 68 )
# Level :  2 Action is R (getpacket Index: 137 )
# Level :  1 Action is R (getpacket Index: 275 )
# There are 10 reconstruction steps
#
# So, it's not the regular decimated wavelet transform!
#
# Let's invert the representation with respect to this basis defined by
# vnnv
#
# vnwrIB <- InvBasis(vnwstT, vnnv)
#
# And also, for completeness let's do an Average Basis reconstruction.
#
# vnwrAB <- AvBasis(vnwstT)
#
# Let's look at the Integrated Squared Error in each case.
#
# sum( (v - vnwrIB)^2)
# [1] 386.2501
#
# sum( (v - vnwrAB)^2)
# [1] 328.4520
#
# So, for this limited example the average basis method does better. Of course,
# for your simulation it could be the other way round. "Occasionally", the
# inverse basis method does better. When does this happen? A good question.
#
# Let's plot the reconstructions and also the original
#
# Not run: plot(vnwrIB, type="l")
# Not run: lines(vnwrAB, lty=2)
# Not run: lines(v, lty=3)
mfilter.select

Provide filter coefficients for multiple wavelets.

Description

This function returns the filter coefficients necessary for doing a discrete multiple wavelet transform (and its inverse).

Usage

mfilter.select(type = "Geronimo")

Arguments

type The name for the multiple wavelet basis. The two possible types are "Geronimo" and "Donovan3".

Details

This function supplies the multiple wavelet filter coefficients required by the mwd function.

A multiple wavelet filter is somewhat different from a single wavelet filter. Firstly the filters are made up of matrices not single coefficients. Secondly there is no simple expression for the high pass coefficients G in terms of the low pass coefficients H, so both sets of coefficients must be specified. Note also that the transpose of the filter coefficients are used in the inverse transform, an unnecessary detail with scalar coefficients. There are two filters available at the moment. Geronimo is the default, and is recommended as it has been checked thoroughly. Donovan3 uses three orthogonal wavelets described in Donovan et al. but this coding has had little testing.


This function fulfils the same purpose as the filter.select function does for the standard DWT wd.

Value

A list is returned with the following eight components which describe the filter:

type The multiple wavelet basis type string.
H A vector containing the low pass filter coefficients.
G A vector containing the high pass pass filter coefficients.
name A character string containing the full name of the filter.
nphi The number of scaling functions in the multiple wavelet basis.
npsi The number of wavelet functions in the multiple wavelet basis.
mfilter.select

NH

The number of matrix coefficients in the filter. This is different from length(H).

ndecim

The decimation factor. I.e. the scale ratio between two successive resolution
levels.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6)

Author(s)

Tim Downie

See Also

accessC.mwd, accessD.mwd, draw.mwd, mfirst.last.mwd.object, mwd, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

#This function is currently used by 'mwr' and 'mwd' in decomposing and
reconstructing, however you can view the coefficients.
#
# look at the filter coefficients for Geronimo multiwavelet
#
#mfilter.select()
#$type:
#  [1] "Geronimo"
#$name:
#  [1] "Geronimo Multiwavelets"
#$nphi:
#  [1] 2
#$npsi:
#  [1] 2
#$NH:
#  [1] 4
#$ndecim:
#  [1] 2
#$H:
#  [1]  0.4242641  0.8000000 -0.0500000 -0.2121320  0.4242641  0.0000000
#  [7]  0.4500000  0.7071068  0.0000000  0.0000000  0.4500000 -0.70710678
# [13] -0.0500000 -0.07071068  0.0000000
#$G:
#  [1] -0.0500000 -0.21213203  0.07071068  0.3000000  0.4500000 -0.70710678
#  [7] -0.63639610  0.0000000  0.4500000 -0.21213203  0.63639610 -0.3000000
# [13] -0.0500000 -0.07071068  0.0000000
Build a first/last database for multiple wavelet transforms.

Description

This function is not intended for user use, but is used by various functions involved in computing and displaying multiple wavelet transforms.

Usage

mfirst.last(LengthH, nlevels, ndecim, type = "wavelet", bc = "periodic")

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>LengthH</td>
<td>Number of filter matrix coefficients.</td>
</tr>
<tr>
<td>nlevels</td>
<td>Number of levels in the decomposition</td>
</tr>
<tr>
<td>ndecim</td>
<td>The decimation scale factor for the multiple wavelet basis.</td>
</tr>
<tr>
<td>type</td>
<td>Whether the transform is non-decimated or ordinary (wavelet). The non-decimated multiple wavelet transform is not yet supported.</td>
</tr>
<tr>
<td>bc</td>
<td>This argument determines how the boundaries of the the function are to be handled. The permitted values are periodic or symmetric</td>
</tr>
</tbody>
</table>

Details

Suppose you begin with $2^m = 2048$ coefficient vectors. At the next level you would expect 1024 smoothed data vectors, and 1024 wavelet vectors, and if bc="periodic" this is indeed what happens. However, if bc="symmetric" you actually need more than 1024 (as the wavelets extend over the edges). The first last database keeps track of where all these "extras" appear and also where they are located in the packed vectors C and D of pyramidal coefficients within wavelet structures.

For examples, given a first.last.c row of

$-2320$

The ‘position’ of the coefficient vectors would be

$C_{-2}, C_{-1}, C_0, C_1, C_2, C_3$

In other words, there are 6 coefficients, starting at -2 and ending at 3, and the first of these ($c_{-2}$) appears at column 20 of the $C$ component matrix of the wavelet structure.

You can “do” first.last in your head for periodic boundary handling but for more general boundary treatments (e.g. symmetric) first.last is indispensable.

The numbers in first last databases were worked out from inequalities derived from: Daubechies, I. (1988).
Value

A first/last database structure, a list containing the following information:

first.last.c A \((m+1)x3\) matrix. The first column specifies the real index of the first coefficient vector of the smoothed data at a level, the 2nd column is the real index of the last coefficient vector, the last column specifies the offset of the first smoothed datum at that level. The offset is used by the C code to work out where the beginning of the sequence is within a packed vector of the pyramid structure. The first and 2nd columns can be used to work out how many numbers there are at a level. If bc="periodic" then the pyramid is a true power of 2 pyramid, that is it starts with a power of 2, and the next level is half of the previous. If bc="symmetric" then the pyramid is nearly exactly a power of 2, but not quite, see the Details section for why this is so.

nvecs.c The number of C coefficient vectors.

first.last.d A \(mx3\) matrix. As for first.last.c but for the wavelet coefficients packed as the D component of a wavelet structure.

nvecs.d The number of D coefficient vectors.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6)

Author(s)

Tim Downie

See Also

accessC.mwd, accessD.mwd, draw.mwd, mwd.object, mwd, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

# To see the housekeeping variables for a decomposition with # 4 filter coefficient matrices # 5 resolution levels and a decimation scale of two # use:
mfirst.last(4,5,2)
# $first.last.c:
# First Last Offset
# [1,] 0 0  62
# [2,] 0 1  60
# [3,] 0 3  56
# [4,] 0 7  48
# [5,] 0 15 32
# [6,] 0 31  0
#
# $nvecs.c:
# [1] 63
modernise

# $first.last.d:
# First Last Offset
# [1,] 0 0 30
# [2,] 0 1 28
# [3,] 0 3 24
# [4,] 0 7 16
# [5,] 0 15 0
#
# $nvecs.d:
# [1] 31

modernise

Generic function to upgrade a V2 WaveThresh object to V4

Description

Not really used in practice. The function IsEarly can be used to tell if an object comes from an earlier version of wavethresh. Note that the earlier version only has a wd.object class object so there is only a method for that.

Usage

modernise(...)

Arguments

... Other objects

Details

Description says all

Value

A modernised version of the object.

Author(s)

G P Nason

See Also

IsEarly, modernise.wd
modernise.wd  Modernise a wd class object

Description
Upgrade a version 2 wd.object to version 4. The function IsEarly can tell if the object comes from an earlier version of WaveThresh.

Usage
## S3 method for class 'wd'
modernise(wd, ...)

Arguments
wd  The wd object you wish to modernise
...
Other arguments

Details
Description says all.

Value
The modernised object.

Author(s)
G P Nason

mpostfilter  Multiwavelet postfilter

Description
A multiwavelet postfilter turns a multivariate sequence into a univariate sequence. As such, the postfilter is used on the inverse transform, it is the inverse of an earlier used prefilter. Not intended for direct user use.

Usage
mpostfilter(C, prefilter.type, filter.type,
  nphi, npsi, ndecim, nlevels, verbose = FALSE)
### Arguments

**C**
- The multivariate sequence you wish to turn back into a univariate one using the inverse of an earlier prefilter operation.

**prefilter.type**
- Controls the type of prefilter (see Tim Downie’s PhD thesis, or references therein. Types include Minimal, Identity, Repeat, Interp, default, Xia, Roach1, Roach3, Donovan3 or Linear

**filter.type**
- The type of multiwavelet: can be Geronimo or Donovan3

**nphi**
- The number of father wavelets in the system

**npsi**
- The number of mother wavelets in the system

**ndecim**
- The ndecim parameter (not apparently used here)

**nlevels**
- The number of levels in the multiwavelet transform

**verbose**
- If TRUE then informative messages are printed as the function progresses

### Details

Description says all

### Value

The appropriate postfiltered data.

### Author(s)

Tim Downie

### See Also

- `mprefilter`, `mwd`
Arguments

data
prefilter.type
filter.type
nlevels
nvecs.c
nphi
npsi
ndecim
verbose

The univariate sequence that you wish to turn into a multivariate one
Controls the type of prefilter (see Tim Downie’s PhD thesis, or references therein.
Types include Minimal, Identity, Repeat, Interp, default, Xia, Roach1, Roach3, Donovan3 or Linear
The type of multiwavelet: can be Geronimo or Donovan3
The number of levels in the multiwavelet transform
Parameter obtained from the mfirst.last function related to the particular filters
The number of father wavelets in the system
The number of mother wavelets in the system
The ndecim parameter (not apparently used here)
If TRUE then informative messages are printed as the function progresses

Details

Description says all

Value

The appropriate prefiltered data.

Author(s)

Tim Downie

See Also

mpostfilter,mwd

Description

This function performs the discrete multiple wavelet transform (DMWT). Using an adaption of
Mallat’s pyramidal algorithm. The DMWT gives vector wavelet coefficients.

Usage

mwd(data, prefilter.type = "default", filter.type = "Geronimo",
  bc ="periodic", verbose = FALSE)
Arguments

data: A vector containing the data you wish to decompose. The length of this vector must be a power of 2 times the dimension of the DMWT (multiplicity of wavelets).

prefilter.type: This chooses the method of preprocessing required. The arguments will depend on filter.type, but "default" will always work.

filter.type: Specifies which multi wavelet filter to use. The options are "Geronimo" (dimension 2) or "Donovan3" (dimension 3). The latter has not been tested fully and may contain bugs. See the function mfilter.select for further details.

bc: specifies the boundary handling. If bc="periodic" the default, then the function you decompose is assumed to be periodic on its interval of definition, if bc="symmetric" then the function beyond its boundaries is assumed to be a symmetric reflection of the function in the boundary.

verbose: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.

Details

The code implements Mallat’s pyramid algorithm adapted for multiple wavelets using Xia, Geronimo, Hardin and Suter, 1996. The method takes a data vector of length $2^J*M$, and preprocesses it. This has two effects, firstly it puts the data into matrix form and then filters it so that the DMWT can operate more efficiently. Most of the technical details are similar to the single wavelet transform except for the matrix algebra considerations, and the prefiltering process. See Downie and Silverman (1998) for further details and how this transform can be used in a statistical context.

Value

An object of class mwd.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1996)

Author(s)

Tim Downie

See Also

accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
# Decompose test.data with multiple wavelet transform and
# plot the wavelet coefficients
#
tdmwd <- mwd(test.data)
## Not run: plot(tdmwd)
# [1] 1.851894 1.851894 1.851894 1.851894 1.851894 1.851894 1.851894 1.851894
# You should see a plot with wavelet coefficients like in
# \code{\link{plot.wd}} but at each coefficient position
# there are two coefficients in two different colours one for each of
# the wavelets at that position.
# # Note the scale for each level is returned by the function.

### mwd.object

**Multiple wavelet decomposition object (1D)**

#### Description

These are objects of class `mwd`

They represent a decomposition of a function with respect to a multiple wavelet basis.

#### Details

To retain your sanity the C and D coefficients should be extracted by the `accessC` and `accessD` functions and put using the `putC` and `putD` functions, rather than by the `$` operator.

#### Value

The following components must be included in a legitimate `mwd` object.

- **C**
  - a matrix containing each level’s smoothed data, each column corresponding to one coefficient vector. The wavelet transform works by applying both a smoothing filter and a bandpass filter to the previous level’s smoothed data. The top level contains data at the highest resolution level. Each of these levels are stored one after the other in this matrix. The matrix ‘fl.dbase$first.last.c’ determines exactly which columns in the matrix, store each level.

- **D**
  - wavelet coefficient matrix. If you were to write down the discrete wavelet transform of a function then columns of D would be the vector coefficients of the wavelet basis function s. Like the C, they are also formed in a pyramidal manner, but stored in a linear matrix. The storage details are to be found in ‘fl.dbase$first.last.d’.
mwd.object

nlevelsWT The number of levels in the pyramidal decomposition that produces the coefficients. The precise number of levels depends on the number of different wavelet functions used and the preprocessing method used, as well as the number of data points used.

fl.dbase The first last database associated with this decomposition. This is a list consisting of 2 integers, and 2 matrices. The matrices detail how the coefficients are stored in the C and D components of the 'mwd.object'. See the help on mfirst.last for more information.

filter a list containing the details of the filter that did the decomposition. See mfilter.select.

type either "wavelet" indicating that the ordinary multiple wavelet transform was performed or "station" indicating that the non-decimated multiple wavelet transform was done.

prefilter Type of preprocessing or prefilter used. This will be specific for the type of multiple wavelet used.

date The date that the transform was performed or the mwd object was last modified.

bc how the boundaries were handled

GENERATION

This class of objects is returned from the mwd function to represent a multiple wavelet decomposition of a function. Many other functions return an object of class mwd.

METHODS

The mwd class of objects has methods for the following generic functions: accessC, accessD, draw, plot, print, putC, putD, summary, threshold, wr.mwd.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie, 1995-6).

Author(s)

Tim Downie

See Also

accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.
Description

This function performs the reconstruction stage of Mallat’s pyramid algorithm adapted for multiple wavelets (see Xia et al. (1996)), i.e. the discrete inverse multiple wavelet transform.

Usage

\[ \text{mwr}(\text{mwd}, \text{prefilter.type} = \text{mwd}\$\text{prefilter}, \text{verbose} = \text{FALSE}, \text{start.level} = 0, \text{returnC} = \text{FALSE}) \]

Arguments

- **mwd**: A multiple wavelet decomposition object as returned by `mwd`.
- **prefilter.type**: Usually best not to change this (i.e. not to use a different prefilter on the reconstruction to the one used on decomposition).
- **verbose**: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
- **start.level**: The level you wish to start reconstruction at. The is usually the first (level 0).
- **returnC**: If this is FALSE then a vector of the same length as the argument data supplied to the function `mwd` that constructed the supplied `mwd.object` is returned. I.e. the reconstructed data. If true then the last level (highest resolution) C coefficients are returned in matrix form. This matrix has not been postprocessed.

Details

The code implements Mallat’s pyramid algorithm adapted for multiple wavelet decompositions (Xia et al. 1996). In the reconstruction the quadrature mirror filters G and H are supplied with C0 and D0, D1, ..., D(J-1) (the wavelet coefficients) and rebuild C1, ..., CJ.

The matrix CJ is postprocessed which returns the full reconstruction.

If `mwd.object` was obtained directly from `mwd` then the original function can be reconstructed exactly. Usually, the `mwd.object` has been modified in some way, for examples, some coefficients set to zero by `threshold`. Mwr then reconstructs the function with that set of wavelet coefficients.

See also Downie and Silverman, 1998

Value

Either a vector containing the final reconstruction or a matrix containing unpostprocessed coefficients.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1996)
newsure

Author(s)
Tim Downie

See Also
accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd, mwd.object, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

# Decompose and then exactly reconstruct test.data
#
test.data <- rnorm(128)
tdecomp <- mwd(test.data)
trecons <- mwr(tdecomp)
#
# Look at accuracy of reconstruction
max(abs(trecons - test.data))
#[1] 2.266631e-12
#
# See also the examples of using \code{\link{wr}} or mwr in
# the \code{examples} section of
# the help for \code{\link{threshold.mwd}}.

Description

Version of sure that acts as subsidiary for threshold.irregwd

Usage

newsure(s, x)

Arguments

s        Vector of standard deviations of coefficients
x        Vector of regular (ie non-normalized) coefficients

Details

Description says all

Value

The SURE threshold
nlevelsWT

Author(s)

Arne Kovac

See Also

sure, threshold.irregwd

---

nlevelsWT

*Returns number of scale (resolution) levels.*

---

Description

Returns the number of scales (or resolutions) in various wavelet objects and for some objects returns the number of scales that would result if processed by a wavelet routine.

This function is generic.

One methods exists at present as most wavelet objects store the number of levels as the nlevelsWT component. The method that exists is nlevelsWT.default

Usage

nlevelsWT(...)

Arguments

... See individual help pages for details.

Details

See individual method help pages for operation and examples.

Value

An integer representing the number of levels associated with the object.

RELEASE

Version 3.6.0 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

nlevelsWT.default
Description

This function returns the number of scale levels associated with either a wavelet type object or an atomic object.

Usage

```r
## Default S3 method:
nlevelsWT(object, ...)
```

Arguments

- `object`: An object for which you wish to determine how many levels it has or is associated with.
- `...`: Any other arguments

Details

This function first checks to see whether the input object has a component called nlevelsWT. If it does then it returns the value of this component. If it does not then it takes the length of the object and then uses the `IsPowerOfTwo` function to return the power of two which equals the length (if any) or NA if the length of the object is not a power of two.

Value

The number of resolution (scale) levels associated with the object.

Author(s)

Version 3.6.0 Copyright Guy Nason 1995

See Also

- `nlevelsWT`

Examples

```r
# Generate some test data
#
test.data <- example.1()$y
#
# Now, this vector is 512 elements long. What number of levels would any # wavelet object be that was associated with this vector?
#```
nlevelsWT(test.data)
# [1] 9
#
# I.e. 2^9=512. Let's check by taking the wavelet transform of the
test data and seeing how many levels it actually has
#
nlevelsWT(wd(test.data))
# [1] 9

nullevels

Set whole resolution levels of coefficients equal to zero.

Description

Generic function which sets whole resolution levels of coefficients equal to zero. Particular methods exist. For objects of class:

- **imwd** use the nullevels.imwd method.
- **wd** use the nullevels.wd method.
- **wst** use the nullevels.wst method.

See individual method help pages for operation and examples.

Usage

nullevels(...)

Arguments

... See individual help pages for details.

Value

An object of the same class as x but with the specified levels set to zero.

RELEASE

Version 3.8.1 Copyright Guy Nason 1997

Author(s)

G P Nason

See Also

nullevels.imwd nullevels.wd nullevels.wst wd.object, wd wst.object wst
**nullevels.imwd**

Sets whole resolution levels of coefficients equal to zero in a `imwd.object`.

### Description

Sets whole resolution levels of coefficients equal to zero in a `imwd.object`.

### Usage

```r
## S3 method for class 'imwd'

nullevels(imwd, levelstonull, ...)
```

### Arguments

- `imwd` An object of class `imwd`.
- `levelstonull` An integer vector specifying which resolution levels of coefficients of `imwd` that you wish to set to zero.
- `...` any other arguments

### Details

Setting whole resolution levels of coefficients to zero can be very useful. For examples, one can construct a linear smoothing method by setting all coefficients above a particular resolution (the primary resolution equal to zero. Also setting particular levels equal to zero can also be useful for removing noise which is specific to a particular resolution level (as long as important signal is not also contained at that level).

Note that this function removes the horizontal, diagonal and vertical detail coefficients at the resolution level specified. It does not remove the father wavelet coefficients at those resolution levels.

To remove individual coefficients on a systematic basis you probably want to look at the `threshold` function.

### Value

An object of class `imwd` where the coefficients in resolution levels specified by `levelstonull` have been set to zero.

### RELEASE

Version 3.9.5 Copyright Guy Nason 1998

### Author(s)

G P Nason
See Also

nullevels.imwd, imwd.object.threshold.

Examples

```r
# Do the wavelet transform of the Lennon image
#
data(lennon)
lenimwd <- imwd(lennon)
#
# Set scales (resolution levels) 2, 4 and 6 equal to zero.
#
lenwdNL <- nullevels(lenimwd, levelstonull=c(2,4,6))
#
# Now let's plot the coefficients using a nice blue-heat colour map
#
## Not run: plot(lenwdNL)
```

---

nullevels.wd

Sets whole resolution levels of coefficients equal to zero in a wd object.

Description

Sets whole resolution levels of coefficients equal to zero in a `wd.object`

Usage

```r
## S3 method for class 'wd'
nullevels(wd, levelstonull, ...)
```

Arguments

- `wd` An object of class `wd`
- `levelstonull` An integer vector specifying which resolution levels of coefficients of `wd` that you wish to set to zero.
- `...` any other arguments

Details

Setting whole resolution levels of coefficients to zero can be very useful. For examples, one can construct a linear smoothing method by setting all coefficients above a particular resolution (the primary resolution) equal to zero. Also setting particular levels equal to zero can also be useful for
removing noise which is specific to a particular resolution level (as long as important signal is not also contained at that level).

Note that this function removes the horizontal, diagonal and vertical detail coefficients at the resolution level specified. It does not remove the father wavelet coefficients at those resolution levels.

To remove individual coefficients on a systematic basis you probably want to look at the \texttt{threshold} function.

**Value**

An object of class \texttt{wd} where the coefficients in resolution levels specified by \texttt{levelstonull} have been set to zero.

**RELEASE**

Version 3.8.1 Copyright Guy Nason 1997

**Author(s)**

G P Nason

**See Also**

\texttt{nullevels,wd,wd.object,threshold}.

**Examples**

```r
# # Generate some test data #
test.data <- example.1()$y
#
# # Do wavelet transform of test.data and plot the wavelet coefficients #
# wds <- wd(test.data)
## Not run: plot(wds)
#
# # Now let us set all the coefficients in ODD resolution levels equal to zero! #
# # This is just to illustrate the capabilities of the function. I cannot #
# imagine you wanting to do this in practice! ##
## wdsn1 <- nullevels(wds, levelstonull = c(1, 3, 5, 7))
# # # Now let's plot the result #
## # # Not run: plot(wdsn1, scaling = "by.level")
# # # Lo and behold the odd levels have been set to zero!
```
Sets whole resolution levels of coefficients equal to zero in a wst object.

Usage

```r
## S3 method for class 'wst'
nullevels(wst, levelstonull, ...)
```

Arguments

- `wst`  An object of class `wst`.
- `levelstonull`  An integer vector specifying which resolution levels of coefficients of `wst` that you wish to set to zero.
- `...`  any other arguments

Details

Setting whole resolution levels of coefficients to zero can be very useful. For examples, one can construct a linear smoothing method by setting all coefficients above a particular resolution (the primary resolution) equal to zero. Also setting particular levels equal to zero can also be useful for removing noise which is specific to a particular resolution level (as long as important signal is not also contained at that level).

To remove individual coefficients on a systematic basis you probably want to look at the `threshold` function.

Value

An object of class `wst` where the coefficients in resolution levels specified by `levelstonull` have been set to zero.

RELEASE

Version 3.8.1 Copyright Guy Nason 1997

Author(s)

G P Nason

See Also

- `nullevels`
- `wst`
- `wst.object`
- `threshold`
numtonv

Examples

# Look at the examples for \code{\link{nullevels.wd}}.
# The operation is almost identical except that \code{\link{wst}}
# objects are replaced by \code{\link{wd}} ones.

numtonv

Convert an index number into a node vector object.

Description

Convert an index number into a node vector object.

Usage

numtonv(number, nlevels)

Arguments

number
The index number of a particular basis within a wavelet object.
nlevels
The number of levels that the wavelet object has (can often be discovered using the nlevels function).

Details

A basis within a (e.g. non-decimated) wavelet object (such as a wst.object) is represented in WaveThresh by a nv or node vector.

A packet-ordered non-decimated wavelet transform object wst (for short) which is the transform of a vector of length n contains n bases. Each basis can be indexed from 0 to (n-1).

A wst.object is simply a fully populated binary tree. There are nlevels levels in the tree with a split at each level. The root of the tree is at level 0, there are two branches at level 1, four at level 2, eight at level 3 and so on. A path through the tree can be constructed by starting at the root and choosing "left" or "right" at each possible branch. For certain data situations this path is constructed using minimum entropy algorithms (for examples MaNoVe). This function (numtonv takes the numerical representation of a path and converts it into a node, vector form suitable for passing to InvBasis to invert the representation according to a basis specified by number.

The least significant digit in number corresponds to deciding on the left/right decision at the fine leaves of the tree (high-frequency structure) and the most significant digit in number corresponds to deciding on the left/right decision at the root. Therefore gradually incrementing number from 0 to 2^{nlevels}-1 steps through all possible bases in the wst object ranging from all decisions being made "left" to all decisions being made "right". The "number" divided by 2^{nlevels} corresponds exactly to the binary number epsilon in Nason and Silverman (1995).

Value

An object of class nv (node vector). This contains information about a path through a wavelet object (a basis in a wavelet object).
RELEASE

Version 3.6.0 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

wst, wst.object, MaNoVe, nv.object, InvBasis, nlevels.

Examples

# Generate some test data
#
test.data <- example.1()$y
#
# Make it noisy
#
ynoise <- test.data + rnorm(512, sd=0.1)
#
# Do packet ordered non-decimated wavelet transform
#
ynwst <- wst(ynoise)
#
# Now threshold the coefficients
#
ynwstT <- threshold(ynwst)
#
# Select basis number 9 (why not?)
#
NodeVector9 <- numtonv(9, nlevelsWT(ynwstT))
#
# Let's print it out to see what it looks like
# (nb, if you're repeating this examples, the basis might be different
# as you may have generated different pseudo random noise to me)
#
NodeVector9
# Level : 8 Action is R (getpacket Index: 1 )
# Level : 7 Action is L (getpacket Index: 2 )
# Level : 6 Action is L (getpacket Index: 4 )
# Level : 5 Action is R (getpacket Index: 9 )
# Level : 4 Action is L (getpacket Index: 18 )
# Level : 3 Action is L (getpacket Index: 36 )
# Level : 2 Action is L (getpacket Index: 72 )
# Level : 1 Action is L (getpacket Index: 144 )
# Level : 0 Action is L (getpacket Index: 288 )
# There are 9 reconstruction steps
#
# The print-out describes the tree through ynwstT that corresponds to
# basis 9.
nv.object

Description

These are objects of classes nv

They represent a basis in a packet-ordered non-decimated wavelet transform object.

Details

A nv object is a description of a basis which is a path through a packet ordered non-decimated wavelet transform. To view the basis just print it! See the examples in numtonv for a print out of its structure.

A similar object exists for describing a basis in a wavelet packet object see nvwp.

Value

The following components must be included in a legitimate ‘nv’ object.

node.list

This is a complicated structure composed of one-dimensional array of \( n \times nlevelsWT \) lists. Each item in the array is itself a list having two components \( \text{upperctrl} \) and \( \text{upperl} \). Each component is described as follows:

\( \text{upperctrl} \) The ‘upperctrl’ item in each is the most important. It consists of a vector of characters. Each character refers to a node in the non-decimated wavelet tree at that level and can only be one of the characters L (for left), R (for right) and S (for stop). Each character in the vector informs reconstruction algorithms that, to do the best thing (whatever the best thing is in any particular case, e.g. select the minimum entropy node downwards), you should select the left/right node or stop at the current node.

\( \text{upperl} \) The ‘upperl’ vector is in 1-1 correspondance with the ‘upperctrl’ vector. Each entry is a number related in some way to the L/R/S entry. (For the minimum entropy this is the minimum entropy achieved by this selection).

\( nlevelsWT \) The number of levels in the wst object that was involved in the creation of the nv object. Nv objects describe a basis relative to a packet ordered non-decimated wavelet transform object and thus must know the number of levels in that object.

GENERATION

This class of objects is returned from the \texttt{MaNoVe.wst} and \texttt{numtonv} functions. The former returns the minimum entropy basis (most sparse basis) obtained using the Coifman-Wickerhauser, 1992 algorithm. The latter permits selection of a basis by an index number.
methods

The rv class of objects has methods for the following generic functions: print, nlevelsWT, InvBasis.

release

Version 3.6.0 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

wst, wst.object, numtonv, print, nlevelsWT, InvBasis, MaNoVe.wst.

plot.imwd

Draw a picture of the 2D wavelet coefficients using image

Description

This function images 2D the absolute values discrete wavelet transform coefficients arising from a imwd.object object.

Usage

## S3 method for class 'imwd'
plot(x, scaling = "by.level", co.type = "abs",
     package = "R", plot.type = "mallat", arrangement = c(3, 3),
     transform = FALSE, tfunction = sqrt, ...)
## S3 method for class 'imwdc'
plot(x, verbose = FALSE, ...)

Arguments

x The 2D imwd object you wish to depict

scaling How coefficient scaling is performed. The options are by.level to scale the coefficients independently by level, anything else causes coefficients to be scaled globally

do.type Can be "abs" for the absolute values of the coefficients to be plotted, can be "mabs" for the negative absolute values or "none" for none of this.

package Can be "R" for the R package, or "S". The latter does less interesting things and results in a simpler plot

plot.type If this argument is "mallat" the coefficients at different scales and orientations are packed into one image and plotted, a format originating from Mallat's early papers on this. The other possibility is "cols" which plots each combination of scale and direction on a separate plot. This latter format is useful for examining coefficients, especially at the coarser scales.
plot.irregwd

```r
plot.irregwd
```

Description

This function plots the variance factors associated with the wavelet coefficients arising from an `irregwd.objects` irregularly spaced wavelet decomposition object.

Details

Description says all

Value

If the `package="S"` argument is set then a matrix is returned containing the image that would have been plotted (and this only works if the `plot.type="mallat"` argument is set also.

Author(s)

G P Nason

See Also

`imwd`, `imwd.object`, `threshold.imwd`

Examples

```r
data(lennon)
lwd <- imwd(lennon)
## Not run: plot(lwd)
## Not run: plot(lwd, col=grey(seq(from=0, to=1, length=100)), transform=TRUE)
```
plot.irregwd

Usage

```r
## S3 method for class 'irregwd'
plot(x, xlabels, first.level = 1,
main = "Wavelet Decomposition Coefficients", scaling = "by.level",
rhlab = FALSE, sub, ...)
```

Arguments

- `x` The `irregwd.objects` object whose coefficients you wish to plot.
- `xlabels` A vector containing the "true" x-axis numbers that went with the vector that was transformed to produce the irregwd object supplied as the first argument to this function. If this argument is missing then the function tries to make up a sensible set of x-axis labels.
- `first.level` The first resolution level to begin plotting at. This argument can be quite useful when you want to suppress some of the coarser levels in the diagram.
- `main` The main title of the plot.
- `scaling` How you want the coefficients to be scaled. The options are: `global` - one scale factor is chosen for the whole plot. The scale factor depends on the variance factor to be included on the plot that has the largest absolute value. The global option is useful when comparing factors that might appear anywhere in the plot; `by.level` - a scale factor is chosen for each resolution level in the plot. The scale factor for a level depends on the variance factor in that level that has the largest absolute value. The by.level option is useful when you wish to compare coefficients within a resolution level.
- `rhlab` If `TRUE` then a set of labels is produced on the right hand axis. The axis labels in this case refer to the scale factors used to scale each level and correspond to value of the largest variance factor (in absolute value) in each scale (when `scaling="by.level"`) or absolutely (when `scaling="global"`). If the `rhlab=FALSE` then no right hand axis labels are produced.
- `sub` A subtitle for the plot.
- `...` Other arguments supplied to the actual plot

Details

Produces a plot similar in style to the ones in Donoho and Johnstone, 1994. This function is basically the same as `plot.wd` except that variance factors and not coefficients are plotted. A variance factor is a number that quantifies the variability of a coefficient induced by the irregular design that was interpolated to a regular grid by the `makegrid` function which is used the by `irregwd` irregular wavelet transform function.

High values of the variance factor correspond to large variance in the wavelet coefficients but due to the irregular design, not the original noise structure on the coefficients.

Value

If `rhlab==TRUE` then the scaling factors applied to each scale level are returned. Otherwise NULL is returned.
plot.mwd

Author(s)

Arne Kovac

Examples

# The help for makegrid contains an example
# of using this function.
#

plot.mwd Use plot on an mwd object.

Description

Plots the wavelet coefficients of a mwd class object.

Usage

## S3 method for class 'mwd'
plot(x, first.level = 1, main = "Wavelet Decomposition Coefficients",
     scaling = "compensated", rhlab = FALSE, sub = x$filter$name,
     NotPlotVal = 0.05, xlab = "Translate", ylab = "Resolution level",
     return.scale = TRUE, colour = (2:(npsi + 1)), ...)

Arguments

x
  The mwd object whose coefficients you wish to plot.

first.level
  The first resolution level to begin plotting at. This argument can be quite useful
  when you want to supress some of the coarser levels in the diagram.

main
  The main title of the plot.

scaling
  How you want the coefficients to be scaled. The options are: "global" - one
  scale factor is chosen for the whole plot. The scale factor depends on the coeffi-
  cient to be included on the plot that has the largest absolute value. The global
  option is useful when comparing coefficients that might appear anywhere in the
  plot; "by.level" - a scale factor is chosen for each resolution level in the plot.
  The scale factor for a level depends on the coefficient in that level that has the
  largest absolute value. The "by.level" option is useful when you wish to com-
  pare coefficients within a resolution level.

  The other option is "compensated" which is the same as "global" except for
  that finer scales' coefficients are scaled up by a factor of SQRT(2) for compensated.
  This latter options is sometimes useful.

rhlab
  If T then a set of labels is produced on the right hand axis. The axis labels in this
  case refer to the scale factors used to scale each level and correspond to value of
  the largest coefficient (in absolute value) in each scale (when scaling="by.level")
  or absolutely (when scaling="global"). If the rhlab argument is FALSE then
  no right hand axis labels are produced.
sub
A subtitle for the plot.

NotPlotVal
Doesn’t seem to be implemented.

xlab
A title for the x-axis

ylab
A title for the y-axis

return.scale
If true (default) the scale for each resolution level is returned

colour
A vector of length \texttt{mwd$npsi}, the values of which are the colours used to plot the coefficients, one for each distinct type of wavelet (with apologies to our American cousins for spelling colour correctly!)

... other arguments to be supplied to plot.

Details

Produces a plot similar to the ones in Donoho and Johnstone, 1994.

Wavelet coefficients for each resolution level are plotted one above the other, with the high resolution coefficients at the bottom, and the low resolution at the top. Each vector is represented by \texttt{mwd$npsi} lines one for each element in the coefficient vector. If colour is supported by the device each element will be represented by a different colour. The coefficients are plotted using the \texttt{segment} function, with a large positive coefficient being plotted above an imaginary horizontal centre line, and a large negative coefficient plotted below it. The position of a coefficient along a line is indicative of the wavelet basis function’s translate number.

The resolution levels are labelled on the left-hand side axis, and the maximum values of the absolute values of the coefficients for the particular level form the right-hand side axis.

The levels of coefficients can be scaled in three ways. If you are not interested in comparing the relative scales of coefficients from different levels, then the default scaling option, "by.level" is what you need. This computes the maximum of the absolute value of the coefficients at a particular level and scales the so that the fit nicely onto the plot. For this option, each level is scaled DIFFERENTLY. To obtain a uniform scale for all the levels specify the “global” option to the scaling argument. This will allow you to make inter-level comparisons.

Value

Axis labels for each resolution level unless \texttt{return.scale=F} when \texttt{NULL} is returned. The axis values are the maximum of the absolute value of the coefficients at that resolution level. They are returned because they are sometimes hard to read on the plot.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6).

Note

A plot of the coefficients contained within the \texttt{mwd} object at each resolution level is produced.

Author(s)

G P Nason
plot.nvwp

See Also

accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd, mwd.object, mwr, print.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

# Generate some test data
#
# test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Decompose test.data with multiple wavelet transform and
# plot the wavelet coefficients
#
# tdmwd <- mwd(test.data)
## Not run: plot(tdmwd)
#[1] 1.851894 1.851894 1.851894 1.851894 1.851894 1.851894 1.851894
#
# You should see a plot with wavelet coefficients like in
# plot.wd but at each coefficient position
# there are two coefficients in two different colours one for each of
# the wavelets at that position.
#
# Note the scale for each level is returned by the function.

---

plot.nvwp  
Depict wavelet packet basis specification

Description

The nvwp class object (generated from MaNoVe.wp for example) contains a wavelet packet basis specification. This function produces a graphical depiction of such a basis.

Usage

## S3 method for class 'nvwp'
plot(x, ...)

Arguments

x  
The wavelet packet node vector you wish to plot, nvwp class object

...  
Other arguments to the central plot function

Details

The vertical axis indicates the resolution level, the horizontal axes indicates the packet index for the finest scales.
Value
Nothing

Author(s)
G P Nason

See Also
MaNoVe.wp, print.nvwp

Examples
v <- rnorm(512)
wp <- wp(v)
vnv <- MaNoVe(wp)
## Not run: plot(vnv)

plot.wd

Plot wavelet transform coefficients.

Description
This function plots discrete wavelet transform coefficients arising from a wd object.

Usage
## S3 method for class 'wd'
plot(x, xlabvals, xlabchars, ylabchars, first.level = 0,
main = "Wavelet Decomposition Coefficients", scaling = "global",
rhlab = FALSE, sub, NotPlotVal = 0.005, xlab = "Translate",
ylab = "Resolution Level",
aspect = "Identity", ...)

Arguments
x The wd class object you wish to plot
xlabvals A vector containing the "true" x-axis numbers that went with the vector that was transformed to produce the wd object supplied as the first argument to this function. If this argument is missing then the function tries to make up a sensible set of x-axis labels.
xlabchars Tickmark labels for the x axis
ylabchars Tickmark labels for the y axis
first.level The first resolution level to begin plotting at. This argument can be quite useful when you want to suppress some of the coarser levels in the diagram.
main The main title of the plot.
plot.wd

scaling How you want the coefficients to be scaled. The options are: global - one scale factor is chosen for the whole plot. The scale factor depends on the coefficient to be included on the plot that has the largest absolute value. The global option is useful when comparing coefficients that might appear anywhere in the plot; by.level - a scale factor is chosen for each resolution level in the plot. The scale factor for a level depends on the coefficient in that level that has the largest absolute value. The by.level option is useful when you wish to compare coefficients within a resolution level.

The two other options are compensated and super which are the same as global except for that finer scales’ coefficients are scaled up by a factor of SQRT(2) for compensated and 2 for super. These latter two options are sometimes useful (more useful for non-decimated wd objects, where they act as a sort of ipndacw matrix operator).

rhlab If TRUE then a set of labels is produced on the right hand axis. The axis labels in this case refer to the scale factors used to scale each level and correspond to value of the largest coefficient (in absolute value) in each scale (when scaling=="by.level") or absolutely (when scaling="global"). If the rhlab argument is FALSE then no right hand axis labels are produced.

sub A subtitle for the plot.

NotPlotVal This argument ensures that if all (scaled) coefficients in a resolution level are below NotPlotVal in absolute value then the whole resolution level is not plotted. This can be useful when plotting a wd object that is sparse (or has been thresholded and necessarily many coefficients might well be zero) as it speeds up the plot because whole levels do not have to be plotted (the function that does the plotting [segments()] is quite a slow function). Note that the value of NotPlotVal refers to scaled coefficients, those that have been scaled by this function (on any resolution level all coefficients are scaled to lie between -0.5 and 0.5).

xlab A title for the x-axis

ylab A title for the y-axis

aspect This argument describes the name (as a character string) of a function to be applied to the coefficients before plotting. By default the argument is "Identity", i.e. the coefficients are plotted as is. This argument is most useful when a complex-valued wavelets are plotted you could use "Mod" to plot the modulus of the coefficients, or "Re" to plot the real parts of the coefficients or "Arg" to plot the argument of the coefficients. Also, the aspect argument can be useful for the ordinary wavelet transforms as well if you are interested in a particular transform of the coefficients.

... fine tuning

Details Produces a plot similar to the ones in Donoho and Johnstone, 1994.

A wavelet decomposition of a signal consists of discrete wavelet coefficients at different scales (resolution levels) and locations. This function plots the coefficients as a pyramid (derived from Mallat’s pyramid algorithm). See the examples below.
The resolution levels are stacked one above the other: coarse scale coefficients are always towards
the top of the plot, fine scale coefficients are always located toward the bottom of the plot. The
location of coefficients increases from left to right across the plot in synchrony with the input signal
to the \texttt{wd} object. In other words the position of a coefficient along a line is indicative of the asso-
ciated wavelet basis function’s translate number. The actual coefficients are plotted using S-Plus’s
\texttt{segments()} function. This plots each coefficient as a vertical line with positive coefficients being
plotted above an imaginary centre line and negative coefficients being plotted below.

The resolution levels are labelled on the left-hand side axis, and if \texttt{rhlab==T} the maximum values
of the absolute values of the coefficients, for the particular level, are plotted on the right-hand axis.

The coefficients in the plot may be scaled in 4 ways. If you are interested in comparing coefficients
in different levels then the default scaling option \texttt{scaling=="global"} is what you need. This
works by finding the coefficient with the largest absolute value amongst all coefficients to be plotted
and then scales all the other coefficients by the largest so that all coefficients lie in the range \(-1/2\)
to \(1/2\). The scaled coefficients are then plotted. If you are not interested in comparing relative
resolution levels and want to see all that goes on within a particular scale then you should use the
scaling option \texttt{scaling=="by.level"} which picks out the largest coefficient (in absolute value)
from each level and scales each level separately. The "compensated" and super options are like the
"global" option except that finer levels are scaled up (as discussed in the arguments list above):
this can be useful when plotting non-decimated wavelet transform coefficients as it emphasizes the
higher frequencies.

\textbf{Value}

If \texttt{rhlab==T} then the scaling factors applied to each scale level are returned. Otherwise \texttt{NULL} is
returned.

\textbf{RELEASE}

Version 3.5.3 Copyright Guy Nason 1994

\textbf{Note}

A plot of the coefficients contained within the \texttt{wd} object is produced.

\textbf{Author(s)}

G P Nason

\textbf{See Also}

\texttt{wd}

\textbf{Examples}

```
# # Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#```
# Decompose test.data and plot the wavelet coefficients
#
wds <- wd(test.data)
## Not run: plot(wds)
#
# Now do the time-ordered non-decimated wavelet transform of the same thing
#
## Not run: wdS <- wd(test.data, type="station")
## Not run: plot(wdS)
#
# Next examples
# ------------
# The chirp signal is also another good examples to use.
#
# Generate some test data
#
test.chirp <- simchirp()$y
## Not run: ts.plot(test.chirp, main="Simulated chirp signal")
#
# Now let's do the time-ordered non-decimated wavelet transform.
# For a change let's use Daubechies least-asymmetric phase wavelet with 8
# vanishing moments (a totally arbitrary choice, please don't read
# anything into it).
#
chirpwdS <- wd(test.chirp, filter.number=8, family="DaubLeAsymm", type="station")
## Not run: plot(chirpwdS, main="TOND WT of Chirp signal")

---

**plot.wp**

*Plot wavelet packet transform coefficients*

**Description**

This function plots wavelet packet transform coefficients arising from a `wp.object` object.

**Usage**

```r
## S3 method for class 'wp'
plot(x, nvwp = NULL, main = "Wavelet Packet Decomposition",
     sub, first.level = 5, scaling = "compensated", dotted.turn.on = 5,
     color.force = FALSE, WaveletColor = 2, NodeVecColor = 3,
     fast = FALSE, SmoothedLines = TRUE, ...)
```

**Arguments**

- `x` The wp object whose coefficients you wish to plot.
- `nvwp` An optional associated wavelet packet node vector class object of class `nvwp`. This object is a list of packets in the wavelet packet table. If this argument is specified then it is possible to highlight the packets in the `nvwp` objects in a different color using the `NodeVecColor` argument.
main The main title of the plot.
sub A subtitle for the plot.
first.level The first resolution level to begin plotting at. This argument can be quite useful when you want to suppress some of the coarser levels in the diagram.
scaling How you want the coefficients to be scaled. The options are: global - one scale factor is chosen for the whole plot. The scale factor depends on the coefficient to be included on the plot that has the largest absolute value. The global option is useful when comparing coefficients that might appear anywhere in the plot; by.level - a scale factor is chosen for each resolution level in the plot. The scale factor for a level depends on the coefficient in that level that has the largest absolute value. The by.level option is useful when you wish to compare coefficients within a resolution level. The other option is compensated which is the same as global except for that finer scales' coefficients are scaled up by a factor of SQRT(2).

dotted.turn.on The plot usually includes some dotted vertical bars that separate wavelet packets to make it clearer which packets are which. This option controls the coarsest resolution level at which dotted lines appear. All levels equal to and finer than this level will receive the vertical dotted lines.
color.force If FALSE then some "clever" code in CanUseMoreThanOneColor tries to figure out how many colours can be used (THIS HAS NOT BEEN MADE TO WORK IN R) and hence whether colour can be used to pick out wavelet packets or elements of a node vector. This option was designed to work with S. It doesn’t work with R and so it is probably best to set color.force=T. In this way no interrogation is done and the lines/packets are plotted in the appropriate colours with no questions asked.
WaveletColor A colour specification for the colour for wavelet coefficients. Wavelet coefficients are a component of wavelet packet coefficients and this option allows them to be drawn in a different color. In R you can use names like "red", "blue" to select the colors. In R you’ll also need to set the color.force option to TRUE.
NodeVecColor If a nwp object is supplied this option can force coefficients that are part of that nwp to be drawn in the specified color. See the explanation for the WaveletColor option above about specification in R.
fast This option no longer does anything.
SmoothedLines If TRUE then the scaling function coefficients are drawn using lines (and look like mini versions of the original). If FALSE then the scaling function coefficients are drawn using the segments function and look like a coarser shadowy version of the original.
...

Details

A wavelet packet object contains wavelet packet coefficients of a signal (usually obtained by the wp wavelet packet transform function). Given a wavelet packet object wp it possesses nlevelsWT(wp) resolution levels. In WaveThresh the coarsest level is level 0 and the finest is level nlevelsWT-1. For wavelet packets the number of packets at level j is 2^(nlevelsWT-j).
This function plots the wavelet packet coefficients. At the bottom of the plot the original input function (if present) is plotted. Then levels above the original plot successively coarser wavelet packet coefficients. From the Mallat transform point of view smoothing goes up off the the left of the picture and detail to the right. The packets are indexed from 0 to the number of packets going from left to right within each resolution level.

The function has the ability to draw wavelet coefficients in a different color using the `WaveletColor` argument.

Optionally, if a node vector wavelet packet object is also supplied, which contains the specification of a basis selected from the packet table, then packets in that node vector can be highlighted in a another colour determined by the `NodeVecColor`.

Packets are drawn on the plot and can be separated by vertical dotted lines. The resolution levels at which this happens can be controlled by the `dotted.turn.on` option. The coarsest resolution level to be drawn is controlled by the `first.level` option.

**Value**

Nothing

**Author(s)**

G P Nason

**See Also**

`MaNoVe`, `wp`, `wp.object`

**Examples**

```r
# # Generate some test data # # v <- DJ.EX()$blocks # # Let's plot these to see what they look like # ## Not run: plot(v, type="l") # # Do a wavelet packet transform # vwp <- wp(v) # # And create a node vector # vnv <- MaNoVe(vwp) # # Now plot the wavelet packets with the associated node vector # ## Not run: plot(vwp, vnv, color.force=T, WaveletColor="red", dotted.turn.on=7) # # The wavelet coefficients are plotted in red. Packets from the node vector
```
# are depicted in green. The node vector gets plotted after the wavelet # coefficients so the green packets overlay the red (retry the plot command # but without the vnv object to see just the # wavelet coefficients). The vertical dotted lines start at resolution # level 7.
#
#

---

**plot.wst**  

Plot packet-ordered non-decimated wavelet transform coefficients.

---

**Description**

This function plots packet-ordered non-decimated wavelet transform coefficients arising from a `wst.object` object.

**Usage**

```r
## S3 method for class 'wst'
plot(x, main = "Nondecimated Wavelet (Packet) Decomposition",
     sub, first.level = 5, scaling = "compensated", dotted.turn.on = 5,
     aspect = "Identity", ...)
```

**Arguments**

- `x`  
  The wst object whose coefficients you wish to plot.

- `main`  
  The main title of the plot.

- `sub`  
  A subtitle for the plot.

- `first.level`  
  The first resolution level to begin plotting at. This argument can be quite useful when you want to suppress some of the coarser levels in the diagram.

- `scaling`  
  How you want the coefficients to be scaled. The options are: `global` - one scale factor is chosen for the whole plot. The scale factor depends on the coefficient to be included on the plot that has the largest absolute value. The global option is useful when comparing coefficients that might appear anywhere in the plot; `by.level` - a scale factor is chosen for each resolution level in the plot. The scale factor for a level depends on the coefficient in that level that has the largest absolute value. The `by.level` option is useful when you wish to compare coefficients within a resolution level. The other option is `compensated` which is the same as global except for that finer scales’ coefficients are scaled up by a factor of `SQRT(2)`.

  *I don’t know why `compensated` is the default option? It is a bit silly.*

- `dotted.turn.on`  
  The plot usually includes some dotted vertical bars that separate wavelet packets to make it clearer which packets are which. This option controls the coarsest resolution level at which dotted lines appear. All levels equal to and finer than this level will receive the vertical dotted lines.
aspect A transform to apply to the coefficients before plotting. If the coefficients are complex-valued and aspect="Identity" then the modulus of the coefficients are plotted.

... Other arguments to plot

Details

A packet-ordered non-decimated wavelet object contains coefficients of a signal (usually obtained by the wst packet-ordered non-decimated wavelet transform, but also functions that derive such objects, such as threshold.wst).

A packet-ordered nondecimated wavelet object, x, possesses nlevelsWT(x) resolution levels. In WaveThresh the coarsest level is level 0 and the finest is level nlevelsWT-1. For packet-ordered nondecimated wavelet the number of blocks (packets) at level j is 2^(nlevelsWT-j).

This function plots the coefficients. At the bottom of the plot the original input function (if present) is plotted. Then levels above the original plot successively coarser wavelet coefficients. Each packet of coefficients is plotted within dotted vertical lines. At the finest level there are two packets: one (the left one) correspond to the wavelet coefficients that would be obtained using the (standard) decimated wavelet transform function, wd, and the other packet are those coefficients that would have been obtained using the standard decimated wavelet transform after a unit cyclic shift. For coarser levels there are more packets corresponding to different cyclic shifts (although the computation is not performed using shifting operations the effect is the same). For full details see Nason and Silverman, 1995.

Packets are drawn on the plot and can be separated by vertical dotted lines. The resolution levels at which this happens can be controlled by the dotted.turn.on option. The coarsest resolution level to be drawn is controlled by the first.level option.

It should be noted that the packets referred to here are just the blocks of nondecimated wavelet coefficients in a packet-ordering. These are different to wavelet packets (produced by wp) and nondecimated wavelet packets (produced by wpst)

Value

Nothing

Author(s)

G P Nason

See Also

MaNoVe,threshold.wst,wst,wst.object

Examples

# # Generate some test data # v <- DJ.EX()$heavi #
# Let's plot these to see what they look like
#
## Not run: plot(v, type="l")
#
# Do a packet-ordered non-decimated wavelet packet transform
#
vwst <- wst(v)
#
# Now plot the coefficients
#
## Not run: plot(vwst)
#
# Note that the "original" function is at the bottom of the plot.
# The finest scale coefficients (two packets) are immediately above.
# Increasingly coarser scale coefficients are above that!
#
plot.wst2D

Plot packet-ordered 2D non-decimated wavelet coefficients.

Description

This function plots packet-ordered 2D non-decimated wavelet coefficients arising from a wst2D object.

Usage

## S3 method for class 'wst2D'
plot(x, plot.type="level", main="", ...)

Arguments

x
The wst2D object whose coefficients you wish to plot.

plot.type
So far the only valid argument is "level" which plots coefficients a level at a time.

main
The main title of the plot.

...
Any other arguments.

Details

The coefficients in a wst2D object are stored in a three-dimensional subarray called wst2D. The first index of the 3D array indexes the resolution level of coefficients: this function with plot.type="level" causes an image of coefficients to be plotted one for each resolution level.

The following corresponds to images produced on S+ graphics devices (e.g. image on motif()). Given a resolution level there are $4^{(n\text{levelsWT}-\text{level})}$ packets within a level. Each packet can be addressed by a base-4 string of length $n\text{levels}-\text{level}$. A zero corresponds to no shift, a 1 to a horizontal shift, a 2 to a vertical shift and a 3 to both a horizontal and vertical shift.
So, for examples, at resolution level nlevelsWT - 1 there are 4 sub-images each containing 4 sub-images. The main sub-images correspond to (clockwise from bottom-left) no shift, horizontal shift, both shift and vertical shifts. The sub-images of the sub-images correspond to the usual smooth, horizontal detail, diagonal detail and vertical detail (clockwise, again from bottom left). Coarser resolution levels correspond to finer shifts! The following figure demonstrates the nlevels - 1 resolution level for the ua image (although the whole image has been rotated by 90 degrees clockwise for display here!):

Value

A plot of the coefficients contained within the wst2D object is produced.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

getpacket.wst2D, putpacket.wst2D, wst2D, wst2D.object.

Examples

```r
# The above picture is one of a series produced by
# plot(uawst2D)
# Where the uawst2D object was produced in the EXAMPLES section
# of the help for \code{\link[wst2D]}
```

plotdenwd

Plot the wavelet coefficients of a p.d.f.

Description

Plots the wavelet coefficients of a density function.

Usage

```r
plotdenwd(wd, xlabvals, xlabchars, ylabchars, first.level=0,
top.level=nlevelsWT(wd)-1,
main="Wavelet Decomposition Coefficients", scaling="global",
rhlab=FALSE, sub, NotPlotVal=0.005, xlab="Translate",
ylab="Resolution Level", aspect="Identity", ...)
```
Arguments

wd Wavelet decomposition object, usually output from denwd, possibly thresholded.
xlabvals X-axis values at which the xlabchars will be printed
xlabchars The x-label characters to be plotted at xlabvals
ylabchars The y-label characters
first.level This specifies how many of the coarse levels of coefficients are omitted from the plot. The default value of 0 means that all levels are plotted.
top.level This tells the plotting routine the true resolution level of the finest level of coefficients. The default results in the coarsest level being labelled 0. The "correct" value can be determined from the empirical scaling function coefficient object (output from denproj) as in the example below.
main The title of the plot.
scaling The type of scaling applied to levels within the plot. This can be "compensated", "by.level" or "global". See plot.wd for further details.
rhlab Determines whether the scale factors applied to each level before plotting are printed as the right hand axis.
sub The plot subtitle
NotPlotVal If the maximum coefficient in a particular level is smaller than NotPlotVal, then the level is not plotted.
xlab The x-axis label
ylab The y-axis label
aspect Function to apply to coefficients before plotting
... Other arguments to the main plot routine

Details

Basically the same as plot.wd except that it copes with the zero boundary conditions used in density estimation. Note that for large filter number wavelets the high level coefficients will appear very squashed compared with the low level coefficients. This is a consequence of the zero boundary conditions and the use of the convention that each coefficient is plotted midway between two coefficients at the next highest level, as in plot.wd.

Value

Axis labels to the right of the picture (scale factors). These are returned as they are sometimes hard to read on the plot.

Author(s)

David Herrick
Examples

# Simulate data from the claw density, find the empirical
# scaling function coefficients, decompose them and plot
# the resulting wavelet coefficients

data <- rclaw(100)
datahr <- denproj(data, J=8, filter.number=2, family="DaubExPhase")
data.wd <- denwd(datahr)
## Not run: plotdenwd(data.wd, top.level=(datahr$res$J-1))
#
# Now use a smoother wavelet
#
datahr <- denproj(data, J=8, filter.number=10, family="DaubLeAsymm")
data.wd <- denwd(datahr)
## Not run: plotdenwd(data.wd, top.level=(datahr$res$J-1))

plotpkt

Sets up a high level plot ready to show the time-frequency plane and
wavelet packet basis slots

Description

Sets up a high level plot ready to add wavelet packet slots using, e.g. addpkt. This function is
used by several routines to begin plotting graphical representations of the time-frequency plane and
spaces for packets.

Usage

plotpkt(J)

Arguments

J         The number of resolution levels associated with the wavelet packet object you
          want to depict

Details

Description says all

Value

Nothing of interest

Author(s)

G P Nason

See Also

addpkt, basisplot, basisplot.BP, basisplot.wp, plot.nvwp
print.BP  
\textit{Print top best basis information for BP class object}

\textbf{Description}

The function \texttt{Best1DCols} works out what are the best packets in a selection of packets. This function prints out what the best packet are.

The \texttt{Best1DCols} is not intended for user use, and hence neither is this print method.

\textbf{Usage}

\begin{verbatim}
## S3 method for class 'BP'
print(x, ...)
\end{verbatim}

\textbf{Arguments}

\begin{itemize}
  \item \texttt{x} The BP object you wish to print
  \item \texttt{...} Other arguments
\end{itemize}

\textbf{Details}

Description says all

\textbf{Value}

None.

\textbf{Author(s)}

G P Nason

\textbf{See Also}

\texttt{Best1DCols}

\textbf{print.imwd}

\textit{Print out information about an imwd object in readable form.}

\textbf{Description}

This function prints out information about an \texttt{imwd.object} in a nice human-readable form.

Note that this function is automatically called by SPlus whenever the name of an \texttt{imwd.object} is typed or whenever such an object is returned to the top level of the S interpreter.
print.imwd

Usage

## S3 method for class 'imwd'
print(x, ...)

Arguments

x An object of class imwd that you wish to print out.
...
This argument actually does nothing in this function!

Details

Prints out information about imwd objects in nice readable format.

Value

The last thing this function does is call summary.imwd so the return value is whatever is returned by this function.

RELEASE

Version 3.0 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

imwd.object, summary.imwd.

Examples

# Generate an imwd object.
#
tmp <- imwd(matrix(0, nrow=32, ncol=32))
#
# Now get R to use print.imwd
#
tmp
# Class 'imwd': Discrete Image Wavelet Transform Object:
# ~~~~ : List with 27 components with names
# nlevelsWT fl.dbase filter type bc date w4L4 w4L1 w4L2 w4L3
# w3L4 w3L1 w3L2 w3L3 w2L4 w2L1 w2L2 w2L3 w1L4 w1L1 w1L2 w1L3 w0L4 w0L1
# w0L2 w0L3 w0Lconstant
#
# $ wNLx are LONG coefficient vectors!
#
# summary(.):
# ---------
# UNcompressed image wavelet decomposition structure
print.imwdc

print.imwdc

Print out information about an imwdc object in readable form.

Description

This function prints out information about an imwdc.object in a nice human-readable form.

Note that this function is automatically called by SPlus whenever the name of an imwdc.object is typed or whenever such an object is returned to the top level of the S interpreter.

Usage

## S3 method for class 'imwdc'
print(x, ...)

Arguments

x An object of class imwdc that you wish to print out.

... This argument actually does nothing in this function!

Details

Prints out information about imwdc objects in nice readable format.

Value

The last thing this function does is call summary.imwdc so the return value is whatever is returned by this function.

RELEASE

Version 2.2 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

imwdc.object, summary.imwdc.
Examples

# Generate an imwd object.
#
# tmp <- imwd(matrix(0, nrow=32, ncol=32))
#
# Now get R to use print.imwd
#
# tmp
#
# Class 'imwd' : Discrete Image Wavelet Transform Object:
# ~~~~ : List with 27 components with names
# nlevelsWT f1.dbase filter type bc date w4L4 w4L1 w4L2 w4L3
# w3L4 w3L1 w3L2 w3L3 w2L4 w2L1 w2L2 w2L3 w1L4 w1L1 w1L2 w1L3 w0L4 w0L1
# w0L2 w0L3 w0Lconstant
#
# $ wNLx are LONG coefficient vectors !
#
# summary(.):
# ~~~~~
# UNcompressed image wavelet decomposition structure
# Levels: 5
# Original image was 32 x 32 pixels.
# Filter was: Daub cmpct on least asymm N=10
# Boundary handling: periodic

---

**print.mwd**

*Use print() on a mwd object.*

**Description**

This function prints out information about an `mwd.object` in a nice human-readable form.

Note that this function is automatically called by SPlus whenever the name of an `mwd.object` is typed or whenever such an object is returned to the top level of the S interpreter.

**Usage**

```r
## S3 method for class 'mwd'
print(x, ...)
```

**Arguments**

- `x` An object of class mwd that you wish to print out.
- `...` This argument actually does nothing in this function!

**Details**

Prints out information about mwd objects in nice readable format.
Value

The last thing this function does is call \texttt{summary.mwd} so the return value is whatever is returned by this function.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6)

Author(s)

G P Nason

See Also

\texttt{accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select.mwd, mwd.object, mwr, plot.mwd, putC.mwd, putD.mwd, summary.mwd, threshold.mwd, wd, wr.mwd}

Examples

```r
# Generate an mwd object.
#
tmp <- mwd(rnorm(32))
#
# Now get Splus to use print.mwd
#
tmp
# Class 'mwd' : Discrete Multiple Wavelet Transform Object:
#    : List with 10 components with names
#    C D nlevelsWT ndata filter fl.dbase type bc prefilter date
#    $ C and $ D are LONG coefficient vectors !
#    Created on : Tue Nov 16 13:16:07 GMT 1999
#    Type of decomposition: wavelet
#
# summary:
#    -------
#    Length of original: 32
#    Levels: 4
#    Filter was: Geronimo Multiwavelets
#    Scaling fns: 2
#    Wavelet fns: 2
#    Prefilter: default
#    Scaling factor: 2
#    Boundary handling: periodic
#    Transform type: wavelet
#    Date: Tue Nov 16 13:16:07 GMT 1999
```
print.nv

Print a node vector object, also used by several other functions to obtain packet list information

Description

Ostensibly prints out node vector information, but also produces packet indexing information for several functions.

Usage

## S3 method for class 'nv'
print(x, printing = TRUE, verbose = FALSE, ...)

Arguments

x
The \texttt{nv.object} that you wish to print

printing
If FALSE then nothing is printed. This argument is here because the results of the printing are also useful to many other routines where you want the results but are not bothered by actually seeing the results

verbose
Not actually used

...
Other arguments

Details

A node vector contains selected basis information, but this is stored as a tree object. Hence, it is not immediately obvious which basis elements have been stored. This function produces a list of the packets at each resolution level that have been selected in the basis. This information is so useful to other functions that the function is used even when printing is not the primary objective.

Value

A list containing two components: \texttt{indexlist} and \texttt{rvector}. The former is a list of packets that were selected at each resolution level. \texttt{rvector} encodes a list of "rotate/non-rotate" instructions in binary. At each selected packet level a decision has to be made whether to select the LH or RH basis element, and this information is stored in \texttt{rvector}.

Author(s)

G P Nason

See Also

\texttt{InvBasis.wst, nv.object, plot.wp}
Examples

v <- rnorm(128)
wst <- wst(v)
vnv <- MaNoVe(wst)
print(vnv)
#Level : 6 Action is R (getpacket Index: 1 )
#Level : 5 Action is L (getpacket Index: 2 )
#Level : 4 Action is L (getpacket Index: 4 )
#Level : 3 Action is R (getpacket Index: 9 )
#Level : 2 Action is L (getpacket Index: 18 )
#There are 6 reconstruction steps
#
# The L or R indicate whether to move to the left or the right basis function
# when descending the node tree
#
#

print.nvwp

Print a wavelet packet node vector object, also used by several other functions to obtain packet list information

Description

Ostensibly prints out wavelet packet node vector information, but also produces packet indexing information for several functions.

Usage

## S3 method for class 'nvwp'
print(x, printing = TRUE, ...)

Arguments

x

The nvwp that you wish to print

printing

If FALSE then nothing is printed. This argument is here because the results of the printing are also useful to many other routines where you want the results but are not bothered by actually seeing the results

...

Other arguments

Details

A node vector contains selected basis information, but this is stored as a tree object. Hence, it is not immediately obvious which basis elements have been stored. This function produces a list of the packets at each resolution level that have been selected in the basis. This information is so useful to other functions that the function is used even when printing is not the primary objective.
Value

A list containing two components: level and pkt. These are the levels and packet indices of the select packets in the basis.

Author(s)

G P Nason

See Also

InvBasis.wp, MaNoVe.wp, plot.nvwp, plot.wp

Examples

v <- rnorm(128)
vwp <- wp(v)
vnv <- MaNoVe(vwp)
print(vnv)
#Level: 6 Packet: 1
#Level: 3 Packet: 0
#Level: 2 Packet: 4
#Level: 2 Packet: 13
#Level: 2 Packet: 15
#Level: 1 Packet: 5
#Level: 1 Packet: 10
#Level: 1 Packet: 13
#Level: 1 Packet: 14
#Level: 1 Packet: 15
#Level: 1 Packet: 16
#Level: 1 Packet: 20
#Level: 1 Packet: 21
#Level: 1 Packet: 24
#Level: 0 Packet: 8
#Level: 0 Packet: 9
#Level: 0 Packet: 12
#Level: 0 Packet: 13
#Level: 0 Packet: 14
#Level: 0 Packet: 15
#Level: 0 Packet: 22
#Level: 0 Packet: 23
#Level: 0 Packet: 24
#Level: 0 Packet: 25
#Level: 0 Packet: 34
#Level: 0 Packet: 35
#Level: 0 Packet: 36
#Level: 0 Packet: 37
#Level: 0 Packet: 38
#Level: 0 Packet: 39
#Level: 0 Packet: 44
#Level: 0 Packet: 45
#Level: 0 Packet: 46
#Level: 0 Packet: 47
print.w2d

Print method for printing w2d class objects

Description

Prints information about a w2d class object. These objects are not typically directly used by a user.

Usage

```r
## S3 method for class 'w2d'
print(x, ...)
```

Arguments

- `x` The w2d class object that you wish to print info about
- `...` Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wpst2discr
Print a w2m class object

Description

These objects are the matrix representation of a nondecimated wavelet packet object.

Usage

```r
## S3 method for class 'w2m'
print(x, maxbasis = 10, ...)
```

Arguments

- `x`: The w2m object to print
- `maxbasis`: The maximum number of basis functions to report on
- `...`: Other arguments

Details

Prints out information about a w2m object. This function gets called during `makewpstRO`, and so you can see its output in the example code in that help function.

Value

None

Author(s)

G P Nason

See Also

`makewpstRO`, `wpst2m`

Examples

```r
#
# See example in makewpstRO
#```
print.wd

Print out information about an wd object in readable form.

Description
This function prints out information about an wd.object in a nice human-readable form.
Note that this function is automatically called by SPlus whenever the name of an wd.object is typed or whenever such an object is returned to the top level of the S interpreter.

Usage
## S3 method for class 'wd'
print(x, ...)

Arguments
x
An object of class wd that you wish to print out.
...
This argument actually does nothing in this function!

Details
Prints out information about wd objects in nice readable format.

Value
The last thing this function does is call summary.wd so the return value is whatever is returned by this function.

RELEASE
Version 3.0 Copyright Guy Nason 1994

Author(s)
G P Nason

See Also
wd.object, summary.wd.

Examples
#
# Generate an wd object.
#
tmp <- wd(rnorm(32))
#
# Now get R to use print.wd
Print out information about an `wd3D` object in a readable form.

**Description**

This function prints out information about an `wd3D` object in a readable form. Note that this function is automatically called by SPlus whenever the name of an `wd3D` object is typed or whenever such an object is returned to the top level of the S interpreter.

**Usage**

```r
## S3 method for class 'wd3D'
print(x, ...)  # An object of class `wd3D` that you wish to print out.
```

**Arguments**

- **x**: An object of class `wd3D` that you wish to print out.
- **...**: This argument actually does nothing in this function!

**Details**

Prints out information about `wd3D` objects in nice readable format.

**Value**

The last thing this function does is call `summary.wd3D` so the return value is whatever is returned by this function.
print.wp

Print out information about an wd object in readable form.

Description

This function prints out information about an \texttt{wp.object} in a nice human-readable form. Note that this function is automatically called by SPlus whenever the name of an \texttt{wp.object} is typed or whenever such an object is returned to the top level of the S interpreter.
Usage

```r
## S3 method for class 'wp'
print(x, ...)
```

Arguments

- `x`: An object of class `wp` that you wish to print out.
- `...`: This argument actually does nothing in this function!

Details

Prints out information about `wp` objects in nice readable format.

Value

The last thing this function does is call `summary.wp` so the return value is whatever is returned by this function.

RELEASE

Version 3.0 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

`wp.object`, `summary.wp`.

Examples

```
# Generate an wp object.
#
tmp <- wp(rnorm(32))
#
# Now get Splus to use print.wp
#
tmp
#
# Now get Splus to use print.wp
#
# tmp
# Class 'wp' : Wavelet Packet Object:
# ~~ : List with 4 components with names
# wp nlevelsWT filter date
#
# $wp is the wavelet packet matrix
#
# Created on : Fri Oct 23 19:59:01 1998
```
print.wpst

# summary(.):
# -------
# Levels: 5
# Length of original: 32
# Filter was: Daub cmpct on least asymm N=10

---

print.wpst

Prints out basic information about a wpst class object

Description

Prints out basic information about a wpst class object generated by the, e.g., wpst function.

Note: stationary wavelet packet objects are now known as nondecimated wavelet packet objects.

Usage

## S3 method for class 'wpst'
print(x, ...)

Arguments

x The wpst object that you wish to print info about

... Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wpst
### Examples

```r
v <- rnorm(128)
wvpst <- wpst(v)
```

```r
# Not run: print(wvpst)

#Class 'wpst' : Stationary Wavelet Packet Transform Object:
# --- : List with 5 components with names
# wpst nlevelsWT avixstart filter date
#
#$wpst is a coefficient vector
#
#Created on : Fri Mar 5 15:06:56 2010
#
#summary(.):
#--------
#Levels: 7
#Length of original: 128
#Filter was: Daub cmpct on least asymm N=10
#Date: Fri Mar 5 15:06:56 2010
```

---

**print.wpstCL**

Prints some information about a wpstCL object

---

**Description**

Prints basic information about a wpstCL object

**Usage**

```r
## S3 method for class 'wpstCL'
print(x, ...)
```

**Arguments**

- `x` 
  wpstCL object to print info about

- `...` 
  Other arguments

**Details**

Description says all

**Value**

Nothing

**Author(s)**

G P Nason
Examples

```r
# Use BabySS and BabyECG data for this example.
#
# Want to predict future values of BabySS from future values of BabyECG
#
# Build model on first 256 values of both
#
# See example in makewpstDO from which this one originates
#
data(BabyECG)
data(BabySS)
BabyModel <- makewpstDO(timeseries=BabyECG[1:256], groups=BabySS[1:256],
                          mincor=0.5)
#
# Now, suppose we get some new data for the BabyECG time series.
# For the purposes of this example, this is just the continuing example
# ie BabyECG[257:512]. We can use our new discriminant model to predict
# new values of BabySS
#
BabySSpred <- wpstCLASS(newTS=BabyECG[257:512], BabyModel)
```

print.wpstDO

Print information about a wpstDO class object

Description

Prints out the type of object, prints out the object’s names, then uses `print.BP` to print out the best single packets.

Usage

```r
## S3 method for class 'wpstDO'
print(x, ...)
```

Arguments

- `x` wpstDO object to print out
- `...` Other information to print
print.wpstDO

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

makewpstDO

Examples

# Use BabySS and BabyECG data for this example.
# Want to predict future values of BabySS from future values of BabyECG
# Build model on first 256 values of both
#
data(BabyECG)
data(BabySS)
BabyModel <- makewpstDO(timeseries=BabyECG[1:256], groups=BabySS[1:256],
mincor=0.5)
#
# The results (ie print out answer)
BabyModel

#Stationary wavelet packet discrimination object
#Composite object containing components:
#BPd  "BP"  "filter"
#Fisher's discrimination: done
#BP component has the following information
#BP class object. Contains "best basis" information
#Components of object:
#nlevelsWT  "BasisMatrix"  "level"  "pkt"  "basiscoef"
#groups
#Number of levels 8
#List of "best" packets
#Level id Packet id Basis coef
#[1,] 4 0 0.7340580
#[2,] 5 0 0.6811251
#[3,] 6 0 0.6443167
#[4,] 3 0 0.6193434
#[5,] 7 0 0.5967620
#[6,] 0 3 0.5473777
#[7,] 1 53 0.5082849
#
print.wpstRO  
*Print a wpstRO class object*

## Description

Prints out a representation of an wpstRO object

## Usage

```r
## S3 method for class 'wpstRO'
print(x, maxbasis = 10, ...)
```

## Arguments

- `x` The wpstRO object to print
- `maxbasis` The maximum number of basis packets to report on
- `...` Other arguments

## Details

Description says all

## Value

None

## Author(s)

G P Nason

## See Also

- `makewpstRO`

## Examples

```r
#  # See example in makewpstRO function
#  #
Print out information about an wst object in readable form.

Description

This function prints out information about an wst.object object in a nice human-readable form.

Usage

```r
## S3 method for class 'wst'
print(x, ...)
```

Arguments

- `x`: The wst.object object to print info on
- `...`: Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wst, wst.object

Examples

```r
# Generate an wst object (a "nonsense" one for # the example).
# vwst <- wst(DJ.EX()$heavi)
# # Now get Splus/R to use print.wst
# vwst
#Class 'wst' : Stationary Wavelet Transform Object:
# --- : List with 5 components with names
#       : wp Carray nlevelsWT filter date
# #$wp and $Carray are the coefficient matrices
```
print.wst2D

Print out information about an wst2d object in a readable form.

Description

This function prints out information about an wst2D.object in a nice human-readable form. Note that this function is automatically called by SPlus whenever the name of an wst2D.object is typed or whenever such an object is returned to the top level of the S interpreter.

Usage

## S3 method for class 'wst2D'
print(x, ...)

Arguments

- **x**: An object of class wst2D that you wish to print out.
- **...**: This argument actually does nothing in this function!

Details

Prints out information about wst2D objects in nice readable format.

Value

The last thing this function does is call summary.wst2D so the return value is whatever is returned by this function.

RELEASE

Version 3.9.6 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

wst2D.object, summary.wst2D.
Examples

# This examples uses the uawst2D object created in the EXAMPLES section of the help page for wst2D
#
#uawst2D
#Class 'wst2D' : 2D Stationary Wavelet Transform Object:
# ~~~~~ : List with 4 components with names
# wst2D nlevelsWT filter date
#
#$wst2D is the coefficient array
#
#Created on : Fri Nov 5 18:06:17 GMT 1999
#
#summary(.):
#--------
#Levels: 8
#Length of original: 256 x 256
#Filter was: Daub cmpct on least asymm N=10
#Date: Fri Nov 5 18:06:17 GMT 1999

PsiJ

Compute discrete autocorrelation wavelets.

Description

This function computes discrete autocorrelation wavelets.

The inner products of the discrete autocorrelation wavelets are computed by the routine ipndacw.

Usage

PsiJ(J, filter.number = 10, family = "DaubLeAsymm", tol = 1e-100,
OPLENGTH=10^7, verbose=FALSE)

Arguments

J
Discrete autocorrelation wavelets will be computed for scales -1 up to scale J.
This number should be a negative integer.

filter.number
The index of the wavelet used to compute the discrete autocorrelation wavelets.

family
The family of wavelet used to compute the discrete autocorrelation wavelets.

tol
In the brute force computation for Daubechies compactly supported wavelets many inner product computations are performed. This tolerance discounts any results which are smaller than tol which effectively defines how long the inner product/autocorrelation products are.

OPLENGTH
This integer variable defines some workspace of length OPLENGTH. The code uses this workspace. If the workspace is not long enough then the routine will stop and probably tell you what OPLENGTH should be set to.

verbose
If TRUE then informative error messages are printed.
Details

This function computes the discrete autocorrelation wavelets. It does not have any direct use for time-scale analysis (e.g. ewspec). However, it is useful to be able to numerically compute the discrete autocorrelation wavelets for arbitrary wavelets and scales as there are still unanswered theoretical questions concerning the wavelets. The method is a brute force – a more elegant solution would probably be based on interpolatory schemes.

Horizontal scale. This routine returns only the values of the discrete autocorrelation wavelets and not their horiztonal positions. Each discrete autocorrelation wavelet is compactly supported with the support determined from the compactly supported wavelet that generates it. See the paper by Nason, von Sachs and Kroisandt which defines the horiztonal scale (but basically the finer scale discrete autocorrelation wavelets are interpolated versions of the coarser ones. When one goes from scale j to j-1 (negative j remember) an extra point is inserted between all of the old points and the discrete autocorrelation wavelet value is computed there. Thus as J tends to negative infinity the numerical approximation tends towards the continuous autocorrelation wavelet.

This function stores any discrete autocorrelation wavelet sets that it computes. The storage mechanism is not as advanced as that for ipndacw and its subsidiary routines rmget and firstdot but helps a little bit. The Psiname function defines the naming convention for objects returned by this function.

Sometimes it is useful to have the discrete autocorrelation wavelets stored in matrix form. The PsiJmat does this.

Note: intermediate calculations are stored in a user-visible environment called WTEnv. Previous versions of wavethresh stored this in the user’s default data space (.GlobalEnv) but wavethresh did not ask permission nor notify the user. You can make these objects persist if you wish.

Value

A list containing -J components, numbered from 1 to -J. The \([j]th \) component contains the discrete autocorrelation wavelet at scale \(j \).

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Author(s)

G P Nason

References


See Also

ewspect, ipndacw, PsiJmat, Psiname.
Examples

# Let us create the discrete autocorrelation wavelets for the Haar wavelet.
# We shall create up to scale 4.
PsiJ(-4, filter.number=1, family="DaubExPhase")
Computing PsiJ
Returning precomputed version
Took 0.00999999 seconds
[[[1]]]:
  [[1]] -0.5  1.0 -0.5
#
[[[2]]]:
  [[1]] -0.25 -0.50  0.25  1.00  0.25 -0.50 -0.25
#
[[[3]]]:
  [[1]] -0.125 -0.250 -0.375 -0.500 -0.125  0.250  0.625  1.000  0.625  0.250
  [[11]] -0.125 -0.500 -0.375 -0.250 -0.125
#
[[[4]]]:
  [[1]] -0.0625 -0.1250 -0.1875 -0.2500 -0.3125 -0.3750 -0.4375 -0.5000 -0.3125
  [[10]] -0.1250  0.0625  0.2500  0.4375  0.6250  0.8125  1.0000  0.8125  0.6250
  [[19]]  0.4375  0.2500  0.0625 -0.1250 -0.3125 -0.5000 -0.4375 -0.3750 -0.3125
  [[28]] -0.2500 -0.1875 -0.1250 -0.0625
#
You can plot the fourth component to get an idea of what the
# autocorrelation wavelet looks like.
# Note that the previous call stores the autocorrelation wavelet
# in Psi.4.1.DaubExPhase. This is mainly so that it doesn't have to
# be recomputed.
# Note that the x-coordinates in the following are approximate.
#
## Not run: plot(seq(from=-1, to=1, length=length(Psi.4.1.DaubExPhase[[4]])),
Psi.4.1.DaubExPhase[[4]], type="l",
xlab = "t", ylab = "Haar Autocorrelation Wavelet")
## End(Not run)
#
# Now let us repeat the above for the Daubechies Least-Asymmetric wavelet
# with 10 vanishing moments.
# We shall create up to scale 6, a higher resolution version than last
# time.
# p6 <- PsiJ(-6, filter.number=10, family="DaubLeAsymm", OPLENGTH=5000)
p6
#[[[1]]]:
  [[1]] 3.537571e-07  5.699601e-16  -7.512135e-06  -7.705013e-06  7.0705013e-15  7.662378e-05
  [[6]] 5.637163e-14  -5.010016e-04  -2.419432e-13  2.368371e-03  9.975939e-13
  [[11]] -8.684028e-03  -1.945435e-12  2.055208e-02  6.245832e-12  -6.773542e-02
  [[16]] 4.704777e-12  1.693386e-01  2.011086e-10  -6.209080e-01  1.000000e+00
PsiJmat

-6.209080e-01 2.011086e-10 1.693386e-01 4.704777e-12 -6.773542e-02
6.245832e-12 2.605208e-02 -1.945435e-12 -8.684028e-03 9.976593e-13
2.368371e-03 -2.419432e-13 -5.010016e-04 5.637163e-14 7.662378e-05
-7.705013e-15 -7.512135e-06 5.699601e-16 3.537571e-07

[[2]]
# scale 2 etc. etc.
#
[[3]] scale 3 etc. etc.
#
scales [[4]] and [[5]]...
#
[[6]]
#
# remaining scale 6 elements...
#
-1.472225e-31 -1.176478e-31 -4.069848e-32 -2.932736e-41 6.855259e-33
5.540202e-33 2.286296e-33 1.164962e-42 -3.134088e-35 3.427783e-44

##
# Let's now plot the 6th component (6th scale, this is the finest
# resolution, all the other scales will be coarser representations)
#
#
## Not run: ts.plot(p6[[6]], xlab = "t",
# ylab = "Daubechies N=10 least-asymmetric Autocorrelation Wavelet")
## End(Not run)

PsiJmat

**Compute discrete autocorrelation wavelets but return result in matrix form.**

**Description**

This function computes discrete autocorrelation wavelets using the PsiJ function but it returns the results as a matrix rather than a list object.

**Usage**

PsiJmat(J, filter.number = 10, family = "DaubLeAsymm", OPLENGTH=10^7)

**Arguments**

J        Discrete autocorrelation wavelets will be computed for scales -1 up to scale J. This number should be a negative integer.
filter.number  The index of the wavelet used to compute the discrete autocorrelation wavelets.
family        The family of wavelet used to compute the discrete autocorrelation wavelets.
OPLENGTH      This integer variable defines some workspace of length OPLENGTH. The code uses this workspace. If the workspace is not long enough then the routine will stop and probably tell you what OPLENGTH should be set to.

Details
The discrete autocorrelation wavelet values are computed using the \texttt{PsiJ} function. This function merely organises them into a matrix form.

Value
A matrix containing \(-J\) rows and a number of columns less than OPLENGTH. Each row contains the values of the discrete autocorrelation wavelet for a different scale. Row one contains the scale \(-1\) coefficients, row two contains the scale \(-2\), and so on.

The number of columns is an odd number. The middle position of each row is the value of the discrete autocorrelation wavelet at zero — this is always 1. The discrete autocorrelation wavelet is symmetric about this point.

Important Apart from the central element none of the other columns line up in this way. This could be improved upon.

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Author(s)
G P Nason

References

See Also
\texttt{PsiJ}

Examples

# As a simple first examples we shall compute the matrix containing # the discrete autocorrelation wavelets up to scale 3.
#PsiJmat(-3, filter.number=1, family="DaubExPhase")
#Computing PsiJ
#Took 0.25 seconds
# Note that this contains 3 rows (since J=-3).
# Each row contains the same discrete autocorrelation wavelet at different
# scales and hence different resolutions.
# Compare to the output given by PsiJ for the
# equivalent wavelet and scales.
# Note also that apart from column 8 which contains 1 (the value of the
# ac wavelet at zero) none of the other columns line up. E.g. the value of
# this wavelet at 1/2 is -0.5: this appears in columns 9, 10 and 12
# we could have written it differently so that they should line up.
# I might do this in the future.
#
# Let's compute the matrix containing the discrete autocorrelation
# wavelets up to scale 6 using Daubechies N=10 least-asymmetric
# wavelets.
# P6mat <- PsiJmat(-6, filter.number=10, family="DaubLeAsymm")
#
# What is the dimension of this matrix?
# dim(P6mat)
# [1] 6 2395
#
# Hmm. Pretty large, so we shan't print it out.
#
# However, these are the ac wavelets... Therefore if we compute their
# inner product we should get the same as if we used the ipndacw
# function directly.
# P6mat
# [1,] 1.839101e+00 3.215934e-01 4.058155e-04 8.460063e-06 4.522125e-08
# [2,] 3.215934e-01 3.035353e+00 6.425188e-01 7.947454e-04 1.683209e-05
# [3,] 4.058155e-04 6.425188e-01 6.070419e+00 1.285038e+00 1.589486e-03
# [4,] 8.460063e-06 7.947454e-04 1.285038e+00 1.214084e+01 2.570075e+00
# [5,] 4.522125e-08 1.683209e-05 1.589486e-03 2.570075e+00 2.428168e+01
# [6,] 5.161675e-10 8.941666e-08 3.366416e-05 3.178972e-03 5.140150e+00
#  [6]
# [1,] 5.161675e-10
# [2,] 8.941666e-08
# [3,] 3.366416e-05
# [4,] 3.178972e-03
# [5,] 5.140150e+00
# [6,] 4.856335e+01
# Let's check it against the ipndacw call
#
# ipndacw(-6, filter.number=10, family="DaubLeAsymm")
#
#-1 1.839181e+00 3.215934e-01 4.058155e-04 8.460063e-06 4.522125e-08
#-2 3.215934e-01 3.035353e+00 6.425188e-01 7.947454e-04 1.683209e-05
#-3 4.058155e-04 6.425188e-01 6.070419e+00 1.285038e+00 1.589486e-03
#-4 8.460063e-06 7.947454e-04 1.285038e+00 1.214084e+01 2.570075e+00
#-5 4.522125e-08 1.683209e-05 1.589486e-03 2.570075e+00 2.428168e+01
#-6 5.161675e-10 8.941666e-08 3.366416e-05 3.178972e-03 5.140150e+00
#
#
# Yep, they're the same.
#

\section*{Psiname} \hspace{1cm} \textit{Return a PsiJ list object style name.}

\subsection*{Description}
This function returns a character string according to a particular format for naming \texttt{PsiJ} objects.

\subsection*{Usage}
Psiname(J, filter.number, family)

\subsection*{Arguments}
\begin{itemize}
  \item \texttt{J} \hspace{1cm} A negative integer representing the order of the \texttt{PsiJ} object.
  \item \texttt{filter.number} \hspace{1cm} The index number of the wavelet used to build the \texttt{PsiJ} object.
  \item \texttt{family} \hspace{1cm} The wavelet family used to build the \texttt{PsiJ} object.
\end{itemize}

\subsection*{Details}
Some of the objects computed by \texttt{PsiJ} take a long time to compute. Hence it is a good idea to store them and reuse them. This function generates a name according to a particular naming scheme that permits a search algorithm to easily find the matrices.

Each object has three defining characteristics: its \texttt{order}, \texttt{filter.number} and \texttt{family}. Each of these three characteristics are concatenated together to form a name.

This function performs exactly the same role as \texttt{rmname} except for objects produced by \texttt{PsiJ}. 
Value
A character string containing the name of an object according to a particular naming scheme.

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Author(s)
G P Nason

References

See Also
PsiJ

Examples

# # What's the name of the order 4 Haar PsiJ object? # Psiname(-4, filter.number=1, family="DaubExPhase") #[1] "Psi.4.1.DaubExPhase" # # What's the name of the order 12 Daubechies least-asymmetric wavelet PsiJ # with 7 vanishing moments? # Psiname(-12, filter.number=7, family="DaubLeAsymm") #[1] "Psi.12.7.DaubLeAsymm"

putC
Put smoothed data (father wavelet) coefficients into wavelet structure

Description
This generic function inserts smooths into various types of wavelet objects.
This function is generic.
Particular methods exist. For objects of class:

wd use the putC.wd method.
wp use the putC.wp method.
wst use the putC.wst method.
See individual method help pages for operation and examples.
See `accessC` if you wish to extract father wavelet coefficients. See `putD` if you wish to insert mother wavelet coefficients.

Usage

```r
putC(...)```

Arguments

... See individual help pages for details.

Value

A wavelet object of the same class as `x` with the new father wavelet coefficients inserted.

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Author(s)

G P Nason

See Also

`putC.wd, putC.wp, putC.wst, accessC, putD`.  

**Description**

The smoothed and original data from a multiple wavelet decomposition structure, `mwd.object`, (e.g. returned from `mwd`) are packed into a single matrix in that structure. This function copies the `mwd.object`, replaces some smoothed data in the copy, and then returns the copy.

Usage

```r
## S3 method for class 'mwd'
putC(mwd, level, M, boundary = FALSE, index = FALSE, ...)
```
Arguments

- **mwd**: Multiple wavelet decomposition structure whose coefficients you wish to replace.
- **level**: The level that you wish to replace.
- **M**: Matrix of replacement coefficients.
- **boundary**: If `boundary` is `FALSE` then only the "real" data is replaced (and it is easy to predict the required length of `M`). If `boundary` is `TRUE` then you can replace the boundary values at a particular level as well (but it is hard to predict the required length of `M`, and the information has to be obtained from the `mfirst.last` database component of `mwd`).
- **index**: If `index` is `TRUE` then the index numbers into the `mwd$C` array where the matrix `M` would be stored is returned. Otherwise, (default) the modified `mwd.object` is returned.
- ... any other arguments

Details

The `mwd` function produces a wavelet decomposition structure.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear matrix of coefficients. `PutC` obtains information about where the smoothed data appears from the `fl.dbase` component of `mwd`, in particular the array `fl.dbase$first.last.c` which gives a complete specification of index numbers and offsets for `mwd$C`.

Note also that this function only puts information into `mwd` class objects. To extract coefficients from `mwd` structures you have to use the `accessC.mwd` function.


Value

An object of class `mwd.object` if `index` is `FALSE`, otherwise the index numbers indicating where the `M` matrix would have been inserted into the `mwd$C` object are returned.

RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6).

Author(s)

G P Nason

See Also

`accessC.mwd`, `accessD.mwd`, `draw.mwd`, `mfirst.last`, `mfilter.select.mwd`, `mwd`, `mwd.object`, `mwr`, `plot.mwd`, `print.mwd`, `putD.mwd`, `summary.mwd`, `threshold.mwd`, `wd`, `wr.mwd`. 
Examples

# Generate an mwd object
#
# tmp <- mwd(rnorm(32))
#
# Now let's examine the finest resolution smooth...
#
accessC(tmp, level=3)
#
#[1,] -0.4669103 -1.3150580 -0.7094966 -0.1979214 0.32079986 0.5052254
#[2,] -0.7645379 -0.8680941 0.1004062 0.6633268 -0.05860848 0.5757286
#
#[,7] [,8]
#[1,] 0.5187380 0.6533843
#[2,] 0.2864293 -0.4433788
#
# A matrix. There are two rows one for each father wavelet in this
two-ple multiple wavelet transform and at level 3 there are 2^3 columns.
#
# Let's set the coefficients of the first father wavelet all equal to zero
# for this examples
#
newcmat <- accessC(tmp, level=3)
newcmat[,1] <- 0
#
# Ok, let's insert it back at level 3
#
tmp2 <- putC(tmp, level=3, M=newcmat)
#
# And check it
#
accessC(tmp2, level=3)
#
#[1,] 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
#[2,] -0.7645379 -0.8680941 0.1004062 0.6633268 -0.05860848 0.5757286 0.2864293
#
#[,8]
#[1,] 0.0000000
#[2,] -0.4433788
#
# Yep, all the first father wavelet coefficients at level 3 are now zero.

putC.wd

Puts a whole resolution level of father wavelet coefficients into wd wavelet object.

Description

Makes a copy of the wd object, replaces some father wavelet coefficients data in the copy, and then returns the copy.
Usage

```r
## S3 method for class 'wd'
putC(wd, level, v, boundary=FALSE, index=FALSE, ...)
```

Arguments

- **wd**: Wavelet decomposition object into which you wish to insert the father wavelet coefficients.
- **level**: the resolution level at which you wish to replace the father wavelet coefficients.
- **v**: the replacement data, this should be of the correct length.
- **boundary**: If boundary is FALSE then only "real" data is replaced. If boundary is TRUE then the boundary (bookeeping) elements are replaced as well. Information about the lengths of the vectors can be found in the `first.last` database function and Nason and Silverman, 1994.
- **index**: If index is TRUE then the index numbers into the 1D array where the coefficient insertion would take place are returned. If index is FALSE (default) then the modified wavelet decomposition object is returned.
- **...**: any other arguments

Details

The function `accessC` obtains the father wavelet coefficients for a particular level. The function `putC.wd` replaces father wavelet coefficients at a particular resolution level and returns a modified wd object reflecting the change.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear vector. `PutC.wd` obtains information about where the smoothed data appears from the `fl.dbase` component of an `wd.object`, in particular the array `fl.dbase$first.last.c`

which gives a complete specification of index numbers and offsets for `wd.object$C`.

Note that this function is method for the generic function `putC`. When the `wd.object` is definitely a wd class object then you only need use the generic version of this function.

Note also that this function only puts information into wd class objects. To extract coefficients from a wd object you have to use the `accessC` function (or more precisely, the `accessC.wd` method).

Value

A `wd` class object containing the modified father wavelet coefficients.

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Author(s)  
G P Nason

See Also  
putC, wd.object, wd, accessC, putD, first.last,

Examples

# Generate an EMPTY wd object:
#
zero <- rep(0, 16)
zerowd <- wd(zero)
#
# Put some random father wavelet coefficients into the object at
# resolution level 2. For the decimated wavelet transform there
# are always 2^i coefficients at resolution level i. So we have to
# insert 4 coefficients
#
mod.zerowd <- putC( zerowd, level=2, v=rnorm(4))
#
# If you use accessC on mod.zerowd you would see that there were only
# coefficients at resolution level 2 where you just put the coefficients.
#
# Now, for a time-ordered non-decimated wavelet transform object the
# procedure is exactly the same EXCEPT that there are going to be
# 16 coefficients at each resolution level. I.e.
#
# Create empty TIME-ORDERED NON-DECIMATED wavelet transform object
#
zerowdS <- wd(zero, type="station")
#
# Now insert 16 random coefficients at resolution level 2
##
mod.zerowdS <- putC(zerowdS, level=2, v=rnorm(16))
#
# Once more if you use accessC on mod.zerowdS you will see that there are
# only coefficients at resolution level 2.

---

**Description**

There are no real smooths to insert in a *wp* wavelet packet object. This function returns an error message. To insert coefficients into a wavelet packet object you should use the *putpacket* collection of functions.
Usage

## S3 method for class 'wp'
putC(wp, ...)

Arguments

wp Wavelet packet object.
...
any other arguments

Value

An error message!

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

putpacket, putpacket.wp.

---

putC.wst

Puts a whole resolution level of father wavelet coefficients into wst wavelet object.

---

Description

Makes a copy of the wst object, replaces a whole resolution level of father wavelet coefficients data in the copy, and then returns the copy.

Usage

## S3 method for class 'wst'
putC(wst, level, value, ...)

Arguments

wst Packet-ordered non-decimated wavelet object into which you wish to insert the father wavelet coefficients.
level the resolution level at which you wish to replace the father wavelet coefficients.
value the replacement data, this should be of the correct length.
...
any other arguments
Details

The function `accessC.wst` obtains the father wavelet coefficients for a particular level. The function `putC.wst` replaces father wavelet coefficients at a particular resolution level and returns a modified wst object reflecting the change.

For the non-decimated wavelet transforms the number of coefficients at each resolution level is the same and equal to $2^n_{\text{levelsWT}}$ where $n_{\text{levels}}$ is the number of levels in the `wst.object`. The number of coefficients at each resolution level is also, of course, the number of data points used to initially form the `wst` object in the first place.

Use the `accessC.wst` to extract whole resolution levels of father wavelet coefficients. Use `accessD.wst` and `putD.wst` to extract/insert whole resolution levels of mother wavelet coefficients. Use the `getpacket.wst` and `putpacket.wst` functions to extract/insert packets of coefficients into a packet-ordered non-decimated wavelet object.

Value

A `wst` class object containing the modified father wavelet coefficients

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Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

`wst.object`, `wst`, `putC`, `accessD.wst`, `putD.wst`, `getpacket.wst`, `putpacket.wst`.

Examples

```r
# # Generate an EMPTY wst object:
#
zero <- rep(0, 16)
zerowst <- wst(zero)
#
# Put some random father wavelet coefficients into the object at
# resolution level 2. For the non-decimated wavelet transform there
# are always 16 coefficients at every resolution level.
#
mod.zerowst <- putC( zerowst, level=2, v=rnorm(16))
#
# If you use accessC on mod.zerowd you would see that there were only
# coefficients at resolution level 2 where you just put the coefficients.
```
Description
This generic function inserts smooths into various types of wavelet objects.
This function is generic.
Particular methods exist. For objects of class:

wd  use the \texttt{putD.wd} method.
wp  use the \texttt{putD.wp} method.
wst use the \texttt{putD.wst} method.

See individual method help pages for operation and examples.
See \texttt{accessD} if you wish to extract mother wavelet coefficients. See \texttt{putC} if you wish to insert father wavelet coefficients.

Usage
\texttt{putD(\ldots)}

Arguments
\ldots See individual help pages for details.

Value
A wavelet object of the same class as \texttt{x} with the new mother wavelet coefficients inserted.

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Version 3.5.3 Copyright Guy Nason 1994

Author(s)
G P Nason

See Also
\texttt{putD.wd, putD.wp, putD.wst, accessD, putC}. 
Description

The wavelet coefficients from a multiple wavelet decomposition structure, `mwd.object`, (e.g. returned from `mwd`) are packed into a single matrix in that structure. This function copies the `mwd.object`, replaces some wavelet coefficients in the copy, and then returns the copy.

Usage

```r
## S3 method for class 'mwd'
putD(mwd, level, M, boundary = FALSE, index = FALSE, ...)
```

Arguments

- `mwd`: Multiple wavelet decomposition structure whose coefficients you wish to replace.
- `level`: The level that you wish to replace.
- `M`: Matrix of replacement coefficients.
- `boundary`: If `boundary` is `FALSE` then only the "real" data is replaced (and it is easy to predict the required length of `M`). If `boundary` is `TRUE` then you can replace the boundary values at a particular level as well (but it is hard to predict the required length of `M`, and the information has to be obtained from the `mfirst.last` database component of `mwd`).
- `index`: If `index` is `TRUE` then the index numbers into the `mwd$D` array where the matrix `M` would be stored is returned. Otherwise, (default) the modified `mwd.object` is returned.
- `...`: any other arguments

Details

The `mwd` function produces a wavelet decomposition structure.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear matrix of coefficients. `PutD` obtains information about where the wavelet coefficients appear from the `fl.dbase` component of `mwd`, in particular the array `fl.dbase$first.last.d` which gives a complete specification of index numbers and offsets for `mwd$D`.

Note also that this function only puts information into `mwd` class objects. To extract coefficients from `mwd` structures you have to use the `accessD.mwd` function.


Value

An object of class `mwd.object` if `index` is `FALSE`, otherwise the index numbers indicating where the `M` matrix would have been inserted into the `mwd$D` object are returned.
RELEASE

Version 3.9.6 (Although Copyright Tim Downie 1995-6).

Author(s)

Tim Downie

See Also

accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select.mwd, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, summary.mwd, threshold.mwd, wd, wr.mwd.

Examples

```r
# Generate an mwd object
#
tmp <- mwd(rnorm(32))
#
# Now let's examine the finest resolution detail...
#
accessD(tmp, level=3)
# [ ,1] [ ,2] [ ,3] [ ,4] [ ,5] [ ,6]
# [1,] 0.8465672 0.4983564 0.3408087 0.1340325 0.5917774 -0.06804291
# [2,] 0.6699962 -0.2535760 -1.0344445 0.2068644 -0.4912086 1.16039885
# [ ,7] [ ,8]
# [1,] -0.6226445 0.2617596
# [2,] -0.4956576 -0.5555795
#
# A matrix. There are two rows one for each mother wavelet in this
# two-ple multiple wavelet transform and at level 3 there are 2^3 columns.
#
# Let's set the coefficients of the first mother wavelet all equal to zero
# for this examples
#
newdmat <- accessD(tmp, level=3)
newdmat[1,] <- 0
#
# Ok, let's insert it back at level 3
#
tmp2 <- putD(tmp, level=3, M=newdmat)
#
# And check it
#
accessD(tmp2, level=3)
# [ ,1] [ ,2] [ ,3] [ ,4] [ ,5] [ ,6] [ ,7]
# [1,] 0.0000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
# [2,] 0.6699962 -0.253576 -1.034445 0.2068644 -0.4912086 1.1603999 -0.4956576
# [ ,8]
# [1,] 0.0000000
# [2,] -0.5555795
```

# Yep, all the first mother wavelet coefficients at level 3 are now zero.

**putD.wd**

Puts a whole resolution level of mother wavelet coefficients into wd wavelet object.

**Description**

Makes a copy of the wd object, replaces some mother wavelet coefficients data in the copy, and then returns the copy.

**Usage**

```r
## S3 method for class 'wd'
putD(wd, level, v, boundary=FALSE, index=FALSE, ...)
```

**Arguments**

- `wd` Wavelet decomposition object into which you wish to insert the mother wavelet coefficients.
- `level` the resolution level at which you wish to replace the mother wavelet coefficients.
- `v` the replacement data, this should be of the correct length.
- `boundary` If boundary is FALSE then only "real" data is replaced. If boundary is TRUE then the boundary (bookeeping) elements are replaced as well. Information about the lengths of the vectors can be found in the `first.last` database function and Nason and Silverman, 1994.
- `index` If index is TRUE then the index numbers into the 1D array where the coefficient insertion would take place are returned. If index is FALSE (default) then the modified wavelet decomposition object is returned.
- `...` any other arguments

**Details**

The function `accessD` obtains the mother wavelet coefficients for a particular level. The function `putD.wd` replaces father wavelet coefficients at a particular resolution level and returns a modified wd object reflecting the change.

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as a linear vector. PutD.wd obtains information about where the smoothed data appears from the fl.dbase component of an wd.object, in particular the array

```r
fl.dbase$first.last.d
```

which gives a complete specification of index numbers and offsets for wd.object$D.
Note that this function is method for the generic function `putD`. When the `wd.object` is definitely a `wd` class object then you only need use the generic version of this function.

Note also that this function only puts information into `wd` class objects. To extract coefficients from a `wd` object you have to use the `accessD` function (or more precisely, the `accessD.wd` method).

**Value**

A `wd` class object containing the modified mother wavelet coefficients.

**Examples**

```r
# Generate an EMPTY wd object:
#
zero <- rep(0, 16)
zerowd <- wd(zero)
#
# Put some random father wavelet coefficients into the object at
# resolution level 2. For the decimated wavelet transform there
# are always 2^i coefficients at resolution level i. So we have to
# insert 4 coefficients
#
mod.zerowd <- putD(zerowd, level=2, v=rnorm(4))
#
# If you plot mod.zerowd you will see that there are only
# coefficients at resolution level 2 where you just put the coefficients.
#
# Now, for a time-ordered non-decimated wavelet transform object the
# procedure is exactly the same EXCEPT that there are going to be
# 16 coefficients at each resolution level. I.e.
#
# Create empty TIME-ORDERED NON-DECIMATED wavelet transform object
#
zerowdS <- wd(zero, type="station")
#
# Now insert 16 random coefficients at resolution level 2
#
mod.zerowdS <- putD(zerowdS, level=2, v=rnorm(16))
#
# Once more if you plot mod.zerowdS then there will only be
```
Description

This function puts an array of wavelet coefficients, corresponding to a particular resolution level into a `wd` wavelet decomposition object.

The pyramid of coefficients in a wavelet decomposition (returned from the `wd3D` function, say) are packed into a single array in WaveThresh3.

Usage

```r
## S3 method for class 'wd3D'
putD(x, v, ...)
```

Arguments

- `x`  3D Wavelet decomposition object into which you wish to insert the wavelet coefficients.
- `v`  This argument is a list with the following components:
  - `a` A 3-dimensional array with each dimension of length equal to two to the power of `lev` which is the level at which you wish to insert the coefficients into `x`.
  - `lev` The level at which you wish to insert the coefficients into `x`.
  - `block` A character string indicating which coefficient block you wish to insert the coefficients into. This can be one of GGG, GGH, GHG, GHH, HGG, HGH, HHG. Additionally this can be HHH when the `lev` argument above is zero.
- `...` Other arguments

Details

The need for this function is a consequence of the pyramidal structure of Mallat’s algorithm and the memory efficiency gain achieved by storing the pyramid as an array.

Note that this function is a method for the generic function `putD`.

Value

A new `wd3D.object` is returned with the coefficients at level `lev` in block given by `block` are replaced by the contents of `a`, if `a` is of the correct dimensions!

RELEASE

Version 3.9.6 Copyright Guy Nason 1997
Author(s)

G P Nason

See Also

accessD, accessD.wd3D, print.wd3D, putD, putDwd3Dcheck, summary.wd3D, threshold.wd3D, wd3D, wd3D.object, wr3D.

Examples

```
# Generate some test data
#
a <- array(rnorm(8*8*8), dim=c(8,8,8))
#
# Perform the 3D DWT
#
awd3D <- wd3D(a)
#
# Replace the second level coefficients by uniform random variables
# in block GGG (for some reason)
#
newsubarray <- list(a = array(runif(4*4*4), dim=c(4,4,4)), lev=2, block="GGG")
awd3D <- putD(awd3D, v=newsubarray)
```

---

**putD.wp**

*Puts a whole resolution level of wavelet packet coefficients into wp wavelet object.*

**Description**

Makes a copy of the wp object, replaces a whole resolution level of wavelet packet coefficients data in the copy, and then returns the copy.

**Usage**

```r
## S3 method for class 'wp'
putD(wp, level, value, ...)
```

**Arguments**

- **wp**
  - Wavelet packet object into which you wish to insert the wavelet packet coefficients.

- **level**
  - the resolution level at which you wish to replace the wavelet packet coefficients.

- **value**
  - the replacement data, this should be of the correct length.

- **...**
  - any other arguments
Details

The function `accessD.wp` obtains the wavelet packet coefficients for a particular level.

For wavelet packet transforms the number of coefficients at each resolution level is the same and equal to $2^{n_{levelsWT}}$ where $n_{levels}$ is the number of levels in the `wp.object`. The number of coefficients at each resolution level is also, of course, the number of data points used to initially form the `wp` object in the first place.

Use the `accessD.wp` to extract whole resolution levels of wavelet packet coefficients.

We don’t recommend that you use this function unless you really know what you are doing. Usually it is more convenient to manipulate individual packets of coefficients using `getpacket/putpacket` functions. If you must use this function to insert whole resolution levels of coefficients you must ensure that the data vector you supply is valid: i.e. contains packet coefficients in the right order.

Value

A `wp` class object containing the modified wavelet packet coefficients.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

`wp.object, wp, accessD, accessD.wp, getpacket.wp, putpacket.wp`.

Examples

```r
# Generate an EMPTY wp object:
#
zero <- rep(0, 16)
zerowp <- wp(zero)
#
# Put some random mother wavelet coefficients into the object at
# resolution level 2. For the wavelet packet transform there
# are always 16 coefficients at every resolution level.
#
mod.zerowp <- putD( zerowp, level=2, v=rnorm(16))
#
# If you plot mod.zerowp you will see that there are only
# coefficients at resolution level 2 where you just put the coefficients.
```
**putD.wst**

*Puts a whole resolution level of mother wavelet coefficients into wst wavelet object.*

---

**Description**

Makes a copy of the `wst` object, replaces a whole resolution level of mother wavelet coefficients data in the copy, and then returns the copy.

**Usage**

```r
## S3 method for class 'wst'
putD(wst, level, value, ...)
```

**Arguments**

- `wst`: Packet-ordered non-decimated wavelet object into which you wish to insert the mother wavelet coefficients.
- `level`: the resolution level at which you wish to replace the mother wavelet coefficients.
- `value`: the replacement data, this should be of the correct length
- `...`: any other arguments

**Details**

The function `accessD.wst` obtains the mother wavelet coefficients for a particular level. The function `putD.wst` replaces mother wavelet coefficients at a particular resolution level and returns a modified `wst` object reflecting the change.

For the non-decimated wavelet transforms the number of coefficients at each resolution level is the same and equal to $2^{n\text{levels}}$ where `nlevels` is the number of levels in the `wst.object`. The number of coefficients at each resolution level is also, of course, the number of data points used to initially form the `wst` object in the first place.

Use the `accessD.wst` to extract whole resolution levels of mother wavelet coefficients. Use `accessC.wst` and `putC.wst` to extract/insert whole resolution levels of father wavelet coefficients. Use the `getpacket.wst` and `putpacket.wst` functions to extract/insert packets of coefficients into a packet-ordered non-decimated wavelet object.

**Value**

A `wst` class object containing the modified mother wavelet coefficients.

**RELEASE**

Version 3.5.3 Copyright Guy Nason 1994

**Author(s)**

G P Nason
putDwd3Dcheck

See Also

\texttt{wst.object, wst.putD, accessD.wst, putC.wst, getpacket.wst, putpacket.wst}.

Examples

\begin{verbatim}
# Generate an EMPTY wst object:
#
zero <- rep(0, 16)
zerowst <- wst(zero)
#
# Put some random mother wavelet coefficients into the object at
# resolution level 2. For the non-decimated wavelet transform there
# are always 16 coefficients at every resolution level.
#
mod.zerowst <- putD( zerowst, level=2, v=rnorm(16))
#
# If you plot mod.zerowst you will see that there are only
# coefficients at resolution level 2 where you just put the coefficients.
\end{verbatim}

\section*{Description}

This function checks the argument list for \texttt{putD.wd3D} and is not meant to be directly called by any user.

\section*{Usage}

\begin{verbatim}
putDwd3Dcheck(lti, dima, block, nlx)
\end{verbatim}

\section*{Arguments}

\begin{description}
\item[lti] At which level of the \texttt{wd3D.object} you wish to insert a block of coefficients.
\item[dima] A vector, of length 3, which specifies the dimension of the block to insert.
\item[block] A character string which specifies which block is being inserted (one of GGG, GGH, GHG, GHH, HGG, HGH, HHG, or HHH).
\item[nlx] The number of levels in the \texttt{wd3D.object} that you wish to insert the coefficients into (can be obtained using the \texttt{nlevelsWT} function).
\end{description}

\section*{Details}

This function merely checks that the dimensions and sizes of the array to be inserted into a \texttt{wd3D.object} using the \texttt{putD.wd3D} function are correct.
**Description**

This generic function inserts packets of coefficients into various types of wavelet objects. This function is generic. Particular methods exist. For objects of class:

- **wp** use the `putpacket.wp` method.
- **wst** use the `putpacket.wst` method.
- **wst2D** use the `putpacket.wst2D` method.

See individual method help pages for operation and examples. Use the `putC` and `putD` function to insert whole resolution levels of coefficients simultaneously.

**Usage**

```r
putpacket(...) 
```

**Arguments**

... See individual help pages for details.

**Value**

A wavelet object of the same class as `x` the input object. The returned wavelet object is the same as the input except that the appropriate packet of coefficients supplied is replaced.
**putpacket.wp**

**Description**

This function inserts a packet of coefficients into a wavelet packet (wp) object.

**Usage**

```r
## S3 method for class 'wp'
putpacket(wp, level, index, packet , ...)
```

**Arguments**

- `wp` Wavelet packet object into which you wish to put the packet.
- `level` The resolution level of the coefficients that you wish to insert.
- `index` The index number within the resolution level of the packet of coefficients that you wish to insert.
- `packet` a vector of coefficients which is the packet you wish to insert.
- `...` any other arguments

**Details**

The coefficients in this structure can be organised into a binary tree with each node in the tree containing a packet of coefficients.

Each packet of coefficients is obtained by chaining together the effect of the two *packet operators* DG and DH: these are the high and low pass quadrature mirror filters of the Mallat pyramid algorithm scheme followed by decimation (see Mallat (1989b)).

Starting with data \(c^J\) at resolution level \(J\) containing \(2^J\) data points the wavelet packet algorithm operates as follows. First DG and DH are applied to \(c^J\) producing \(d^{J-1}\) and \(c^{J-1}\) respectively. Each of these sets of coefficients is of length one half of the original data: i.e. \(2^{J-1}\). Each of these sets of coefficients is a set of *wavelet packet coefficients*. The algorithm then applies both DG and DH to both \(d^{J-1}\) and \(c^{J-1}\) to form four sets of coefficients at level \(J-2\). Both operators are used again on the four sets to produce 8 sets, then again on the 8 sets to form 16 sets and so on. At level \(j=J,...,0\) there are \(2^{J-j}\) packets of coefficients each containing \(2^j\) coefficients.
This function enables whole packets of coefficients to be inserted at any resolution level. The index argument chooses a particular packet within each level and thus ranges from 0 (which always refer to the father wavelet coefficients), 1 (which always refer to the mother wavelet coefficients) up to $2^{J-j}$.

Value

An object of class \texttt{wp.object} which is the same as the input \texttt{wp.object} except it now has a modified packet of coefficients.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

\texttt{wp}, \texttt{getpacket.wp}, \texttt{putpacket}.

Examples

```r
# Take the wavelet packet transform of some random data
#
# MyWP <- wp(rnorm(1:512))
#
# The above data set was 2^9 in length. Therefore there are
# coefficients at resolution levels 0, 1, 2, ..., and 8.
#
# The high resolution coefficients are at level 8.
# There should be 256 DG coefficients and 256 DH coefficients
#
# length(getpacket(MyWP, level=8, index=0))
# [1] 256
# length(getpacket(MyWP, level=8, index=1))
# [1] 256
#
# The next command shows that there are only two packets at level 8
#
# getpacket(MyWP, level=8, index=2)
# Index was too high, maximum for this level is 1
# Error in getpacket.wp(MyWP, level = 8, index = 2): Error occurred
# Dumped
#
# There should be 4 coefficients at resolution level 2
#
# The father wavelet coefficients are (index=0)
# getpacket(MyWP, level=2, index=0)
# [1] 0.9736576 0.5579501 0.3100629 -0.3834068
```
# The mother wavelet coefficients are (index=1)
getpacket(MyWP, level=2, index=1)
# [1] 0.72871405 0.04356728 -0.43175307 1.77291483
#
# Well, that exercised the getpacket.wp
# function. Now that we know that level 2 coefficients have 4 coefficients
# let's insert some into the MyWP object.
#
MyWP <- putpacket(MyWP, level=2, index=0, packet=c(21,32,67,89))
#
# O.k. that was painless. Now let's check that the correct coefficients
# were inserted.
#
getpacket(MyWP, level=2, index=0)
#[1] 21 32 67 89
#
# Yep. The correct coefficients were inserted.

---

### putpacket.wst

*Put a packet of coefficients into a packet ordered non-decimated wavelet object (wst).*

#### Description

This function inserts a packet of coefficients into a packet-ordered non-decimated wavelet object (*wst*) object. The *wst* objects are computed by the *wst* function amongst others.

#### Usage

```r
## S3 method for class 'wst'
putpacket(wst, level, index, packet, ...)  
```

#### Arguments

- **wst**
  - Packet-ordered non-decimated wavelet object into which you wish to insert the packet.
- **level**
  - The resolution level of the coefficients that you wish to insert.
- **index**
  - The index number within the resolution level of the packet of coefficients that you wish to insert.
- **packet**
  - A vector of coefficients that you wish to insert into the *wst* object. The length that the packet has to may be determined by extracting the same packet of coefficients using the `getpacket.wst` function and using the S-Plus length function to determine the length!
- **...**
  - any other arguments
Details
This function actually calls the `putpacket.wp` to do the insertion.
In the future this function will be extended to insert father wavelet coefficients as well.

Value
An object of class `wst.object` containing the packet ordered non-decimated wavelet coefficients that have been modified: i.e. with packet inserted.

RELEASE
Version 3.9 Copyright Guy Nason 1998

Author(s)
G P Nason

See Also
`getpacket.wst`, `putpacket`, `putpacket.wp`, `wst`, `wst.object`.

Examples
```r
# Take the packet-ordered non-decimated transform of some random data
#
MyWST <- wst(rnorm(1:512))
#
# The above data set was 2^9 in length. Therefore there are
# coefficients at resolution levels 0, 1, 2, ..., and 8.
#
# The high resolution coefficients are at level 8.
# There should be 256 coefficients at level 8 in index location 0 and 1.
#
length(getpacket(MyWST, level=8, index=0))
# [1] 256
length(getpacket(MyWST, level=8, index=1))
# [1] 256
#
# There should be 4 coefficients at resolution level 2
#
getpacket(MyWST, level=2, index=0)
# [1] -0.92103095 0.70125471 0.07361174 -0.43467375
#
# O.k. Let's insert the packet containing the numbers 19,42,21,32
#
NewMyWST <- putpacket(MyWST, level=2, index=0, packet=c(19,42,31,32))
#
# Let's check that it put the numbers in correctly by reaccessing that
# packet...
#```
getpacket(NewMyST, level=2, index=0)
# [1] 19 42 31 32
#
# Yep. It inserted the packet correctly.

---

**putpacket.wst2D**

*Replace packet of coefficients in a two-dimensional non-decimated wavelet object (wst2D).*

---

**Description**

This function replaces a packet of coefficients from a two-dimensional non-decimated wavelet (wst2D) object and returns the modified object.

**Usage**

```r
## S3 method for class 'wst2D'
putpacket(wst2D, level, index, type="S", packet, Ccode=TRUE, ...)
```

**Arguments**

- `wst2D`: 2D non-decimated wavelet object containing the coefficients you wish to replace.
- `level`: The resolution level of the coefficients that you wish to replace. Can range from 0 to `nlevelsWT(wpst) - 1`.
- `index`: The index number within the resolution level of the packet of coefficients that you wish to replace. Index is a base-4 number which is \( r \) digits long. Each digit can be 0, 1, 2 or 3 corresponding to no shifts, horizontal shift, vertical shift or horizontal and vertical shifts. The number \( r \) indicates the depth of the resolution level from the data resolution i.e. where \( r = nlevelsWT - level \).
  Where there is a string of more than one digit the left most digits correspond to finest scale shift selection, the right most digits to the coarser scales (I think).
- `packet`: A square matrix of dimension \( 2^\text{level} \) which contains the new coefficients that you wish to insert.
- `type`: This is a one letter character string: one of "S", "H", "V" or "D" for the smooth coefficients, horizontal, vertical or diagonal detail.
- `Ccode`: If T then fast C code is used to obtain the packet, otherwise slow SPlus code is used. Unless you have some special reason always use the C code (and leave the argument at its default).
- `...`: any other arguments
Details

The `wst2D` function creates a `wst2D` class object. Starting with a smooth the operators H, G, GS and HS (where G, H are the usual Mallat operators and S is the shift-by-one operator) are operated first on the rows and then the columns: i.e. so each of the operators HH, HG, GH, GG, HSH, HSG, GSH, GSG HHS, GHS, HGS, GGS HSHS, HSGS, GSHS and GSGS are applied. Then the same collection of operators is applied to all the derived smooths, i.e. HH, HSH, HHS and HSHS.

So the next level is obtained from the previous level with basically HH, HG, GH and GG but with extra shifts in the horizontal, vertical and horizontal and vertical directions. The index provides a way to enumerate the paths through this tree where each smooth has 4 children and indexed by a number between 0 and 3.

Each of the 4 children has 4 components: a smooth, horizontal, vertical and diagonal detail, much in the same way as for the Mallat 2D wavelet transform implemented in the `WaveThresh` function `imwd`.

Value

An object of class `wst2D` with coefficients at resolution level level, packet index and orientation given by type replaced by the matrix packet.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

`getpacket.wst2D`, `wst2D`, `wst2D.object`.

Examples

```
# Create a random image.
#
#myrand <- matrix(rnorm(16), nrow=4, ncol=4)
#myrand
#
#[1,] 0.01692807 0.1400891 -0.38225727 0.3372708
#[2,] -0.79799841 -0.3306080 1.59789958 -1.0606204
#[3,] 0.29151629 -0.2028172 -0.02346776 0.5833292
#[4,] -2.21505532 -0.3591296 -0.39354119 0.6147043
#
# Do the 2D non-decimated wavelet transform
#
#myrwst2D <- wst2D(myrand)
#
# Let's access the finest scale detail, not shifted in the vertical
# direction.
```
#
getpacket(myrwst2D, nlevelsWT(myrwst2D)-1, index=0, type="V")
#
[,1] [,2]
[1,] -0.1626819 -1.3244064
[2,] 1.4113247 -0.7383336
#
# Let's put some zeros in instead...
#
zmat <- matrix(c(0,0,0,0), 2,2)
newwst2D <- putpacket(myrwst2D, nlevelsWT(myrwst2D)-1,
index=0, packet=zmat, type="V")
#
# And now look at the same packet as before
#
getpacket(myrwst2D, nlevelsWT(myrwst2D)-1, index=0, type="V")
#
[,1] [,2]
[1,] 0 0
[2,] 0 0
#
# Yup, packet insertion o.k.

rcov

Computes robust estimate of covariance matrix

Description

Computes a robust correlation matrix from x.

Usage

rcov(x)

Arguments

x

Matrix that you wish to find robust covariance of. Number of variables is number of rows, number of observations is number of columns. This is the opposite way round to the convention expected by var, for example

Details

Method originates from Huber's "Robust Statistics" book. Note that the columns of x must be observations, this is the opposite way around to the usual way for functions like var.

Value

The robust covariance matrix

Author(s)

Tim Downie
See Also

threshold.mwd

Examples

# A standard normal data matrix with 3 variables, 100 observations
#
v <- matrix(rnorm(100*3), nrow=3, ncol=100)
#
# Robust covariance
#
rcov(v)

---

rfft

Real Fast Fourier transform

Description

Compute a real Fast Fourier transform of \( x \).

Usage

rfft(x)

Arguments

x

The vector whose Fourier transform you wish to take

Details

Given a vector \( x \) this function computes the real continuous Fourier transform of \( x \), i.e. it regards \( x \) as points on a periodic function on \([0,1]\) starting at 0, and finding the coefficients of the functions \( 1, \sqrt{2} \cos(2\pi t), \sqrt{2} \sin(2\pi t) \), etc. that gives the expansion of the interpolant of \( x \). The number of terms in the expansion is the length of \( x \). If \( x \) is of even length, the last coefficient will be that of a cosine term with no matching sine.

Value

Returns the Fourier coefficients

Author(s)

Bernard Silverman

See Also

LocalSpec.wd, rfftinv
Examples

```r
x <- seq(from=0, to=2*pi, length=150)
s1 <- sin(10*x)
s2 <- sin(7*x)
s <- s1 + s2
w <- rfft(s)
## Not run: ts.plot(w)
#
# Should see two peaks, corresponding to the two sines at different frequencies
#
```

---

### rfftinv

**Inverse real FFT, inverse of rfft**

#### Description

Inverse function of `rfft`

#### Usage

```r
rfftinv(rz, n = length(rz))
```

#### Arguments

- `rz` The Fourier coefficients to invert
- `n` The number of coefficients

#### Details

Just the inverse function of `rfft`.

#### Value

The inverse FT of the input

#### Author(s)

Bernard Silverman

#### See Also

- `rfft`
rfftwt  

*Weight a Fourier series sequence by a set of weights*

**Description**

Weight the real Fourier series \( x_{\text{rfft}} \) of even length by a weight sequence \( w_t \). The first term of \( x_{\text{rfft}} \) is left alone, and the weights are then applied to pairs of terms in \( x_{\text{rfft}} \). Note: \( w_t \) is half the length of \( x_{\text{rfft}} \).

**Usage**

\[ \text{rfftwt}(x_{\text{rfft}}, w_t) \]

**Arguments**

- \( x_{\text{rfft}} \): The Fourier series sequence to weight
- \( w_t \): The weights

**Details**

Description says all

**Value**

The weighted sequence

**Author(s)**

Bernard Silverman

**See Also**

- `rfft`

---

rm.det  

*Set coarse levels of a wavelets on the interval transform object to zero*

**Description**

Set the wavelet coefficients of certain coarse levels for a "wavelets on the interval" object equal to zero. The operation of this function is somewhat similar to the `nulllevels` function, but for objects associated with the "wavelets on the interval code".

**Usage**

\[ \text{rm.det}(\text{wd.int.obj}) \]
Arguments

wd.int.obj       the object whose coarse levels you wish to set to zero

Details

The "wavelets on the interval" code is contained within the wd function. All levels coarser than (but not including) the wd.int.obj$current.scale are set to zero.

Value

A wd.object of type="interval" containing the modified input object with certain coarse levels set to zero.

Author(s)

Piotr Fryzlewicz

See Also

nullevels, wd

Description

Returns the integer corresponding to the smallest order ipndacw matrix of greater than or equal to order than the order, J requested.

Not really intended for user use.

Usage

rmget(requestJ, filter.number, family)

Arguments

requestJ       A positive integer representing the order of the ipndacw matrix that is required.
filter.number The index number of the wavelet used to build the ipndacw matrix that is required.
family         The wavelet family used to build the ipndacw matrix that is required.
Some of the matrices computed by \texttt{ipndacw} take a long time to compute. Hence it is a good idea to store them and reuse them.

This function is asked to find an \texttt{ipndacw} matrix of a particular order, \texttt{filter.number} and \texttt{family}. The function steps through all of the directories in the \texttt{search()} list collecting names of all \texttt{ipndacw} matrices having the same \texttt{filter.number} and \texttt{family} characteristics. It then keeps any names where the \texttt{order} is larger than, or equal to, the requested order. This means that a suitable \texttt{ipndacw} matrix of the same or larger order is visible in one of the \texttt{search()} directories. The matrix name with the smallest \texttt{order} is selected and the \texttt{order} of the matrix is returned. The routine that called this function can then get() the matrix and either use it "as is" or extract the top-left hand corner of it if \texttt{requestJ} is less than the order returned by this function.

If no such matrix, as described by the previous paragraph, exists then this function returns \texttt{NULL}.

This function calls the subsidiary routine \texttt{firstdot}.

Value

If a matrix of order larger than or equal to the requested order exists somewhere on the search path and the \texttt{filter.number} and \texttt{family} is as specified then its order is returned. If more than one such matrix exists then the order of the smallest one larger than or equal to the requested one is returned.

If no such matrix exists the function returns \texttt{NULL}.

RELEASE

Version 3.9 Copyright Guy Nason 1998

Author(s)

G P Nason

References


See Also

\texttt{firstdot}, \texttt{ipndacw}, \texttt{rmname}.

Examples

```r
# Suppose there are no matrices in the search path.
#
# Let's look for the matrix rm.4.1.DaubExPhase (Haar wavelet matrix of
# order 4)
#
rmget(requestJ=4, filter.number=1, family="DaubExPhase")
#NULL
```
# I.e. a NULL return code. So there were no suitable matrices.
# If we create two Haar ipndacw matrix of order 7 and 8
ipndacw(-7, filter.number=1, family="DaubExPhase")
ipndacw(-8, filter.number=1, family="DaubExPhase")
# Now let's repeat the earlier search
rmget(requestJ=4, filter.number=1, family="DaubExPhase")
#[1] 7
#
# So, as we the smallest Haar ipndacw matrix available larger than
# the requested order of 4 is "7".
#

---

rmname

Return a ipndacw matrix style name.

Description

This function returns a character string according to a particular format for naming ipndacw matrices.

Usage

rmname(J, filter.number, family)

Arguments

J
A negative integer representing the order of the ipndacw matrix.

filter.number
The index number of the wavelet used to build the ipndacw matrix.

family
The wavelet family used to build the ipndacw matrix.

Details

Some of the matrices computed by ipndacw take a long time to compute. Hence it is a good idea to store them and reuse them. This function generates a name according to a particular naming scheme that permits a search algorithm to easily find the matrices.

Each matrix has three defining characteristics: its order, filter.number and family. Each of these three characteristics are concatenated together to form a name.

Value

A character string containing the name of a matrix according to a particular naming scheme.
DESCRIPTION

Cyclically shifts the elements of a vector one place to the right. The right-most element becomes the first element.

USAGE

rotateback(v)

ARGUMENTS

v The vector to shift
Details

Subsidiary function used by the \texttt{av.basis} function which is the R function component of the \texttt{AvBasis.wst} function.

Value

The rotated vector

Author(s)

G P Nason

Examples

\begin{verbatim}
# # Here is a test vector # v <- 1:10 # # # Apply this function # rotateback(v) #[1] 10 1 2 3 4 5 6 7 8 9 # # # A silly little function really!
\end{verbatim}

\begin{description}
\item[rsswav] \textit{Compute mean residual sum of squares for odd prediction of even ordinates and vice versa}
\end{description}

Description

Compute mean of residual sum of squares (RSS) for odd prediction of even ordinates and vice versa using wavelet shrinkage with a specified threshold. This is a subsidiary routine of the \texttt{WaveletCV} cross validation function. A version implemented in C exists called \texttt{Crsswav}.

Usage

\begin{verbatim}
rsswav(noisy, value = 1, filter.number = 10, family = "DaubLeAsymm", thresh.type = "hard", ll = 3)
\end{verbatim}

Arguments

\begin{itemize}
\item \textbf{noisy} A vector of dyadic (power of two) length that contains the noisy data that you wish to compute the averaged RSS for.
\item \textbf{value} The specified threshold.
\item \textbf{filter.number} This selects the smoothness of wavelet that you want to perform wavelet shrinkage by cross-validation.
\end{itemize}
family specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

thresh.type this option specifies the thresholding type which can be "hard" or "soft".

ll The primary resolution that you wish to assume. No wavelet coefficients that are on coarser scales than ll will be thresholded.

Details

Note: a faster C based implementation of this function called Crsswav is available. It takes the same arguments and returns the same values.

Two-fold cross validation can be computed for a wd object using the "cv" policy option in threshold.wd. As part of this procedure for each threshold value that the CV optimisation algorithm selects a RSS value must be computed (the CV optimisation algorithm seeks to minimize this RSS value).

The RSS value computed is this. First, the even and odd indexed values are separated. The even values are used to construct an estimate of the odd true values using wavelet shrinkage with the given threshold. The sum of squares between the estimate and the noisy odds is computed. An equivalent calculation is performed by swapping the odds and evens. The two RSS values are then averaged and the average returned. This algorithm is described more fully in Nason, (1996).

Value

A list with the following components

ssq The RSS value that was computed

df The dof value computed on the thresholded wavelet transform of the data with the given threshold and thresholding options. (Although this is not really used for anything).

value The value argument that was specified.

type the thresh.type argument that was specified.

lev The vector ll:(nlevelsWT(noisy)-1) (i.e. the levels that were thresholded).

Author(s)

G P Nason

See Also

Crsswav, threshold.wd, WaveletCV
ScalingFunction  

Compute scaling functions on internally predefined grid

Description

This is a subsidiary routine not intended to be called by a user: use `draw` instead. Generates scaling functions by inserting a Kronecker delta function into the bottom of the inverse DWT and repeating the inverting steps.

Usage

```r
ScalingFunction(filter.number = 10, family = "DaubLeAsymm", resolution = 4096, itlevels = 50)
```

Arguments

- `filter.number`: The filter number of the associated wavelet. See `filter.select`
- `family`: The family of the associated wavelet. See `filter.select`
- `resolution`: The nominal resolution, the actual grid size might be larger than this
- `itlevels`: The number of complete filtering operations to generate the answer

Details

Description says all

Value

A list containing the x and y values of the required scaling function.

Author(s)

G P Nason

See Also

`draw`
Shannon.entropy

Description

Computes Shannon entropy of the squares of a set of coefficients.

Usage

Shannon.entropy(v, zilchtol=1e-300)

Arguments

v A vector of coefficients (e.g. wavelet coefficients).

zilchtol A small number. Any number smaller than this is considered to be zero for the purposes of this function.

Details

This function computes the Shannon entropy of the squares of a set of coefficients. The squares are used because we are only interested in the entropy of the energy of the coefficients, not their actual sign.

The entropy of the squares of v is given by \( \sum (v^2 \ast \log(v^2)) \). In this implementation any zero coefficients (determined by being less than zilchtol) have a zero contribution to the entropy.

The Shannon entropy measures how "evenly spread" a set of numbers is. If the size of the entries in a vector is approximately evenly spread then the Shannon entropy is large. If the vector is sparsely populated or the entries are very different then the Shannon entropy is near zero. Note that the input vectors to this function usually have their norm normalized so that diversity of coefficients corresponds to sparsity.

Value

A number representing the Shannon entropy of the input vector.

RELEASE

Version 3.7.2 Copyright Guy Nason 1996

Author(s)

G P Nason

See Also

MaNoVe.wst, wst,
Examples

```r
# # Generate some test data # # # A sparse set # Shannon.entropy(c(1,0,0,0)) #0 # # A evenly spread set # Shannon.entropy( rep( 1/ sqrt(4), 4 )) #1.386294
```

**simchirp**

*Compute and return simulated chirp function.*

**Description**

This function computes and returns the coordinates of the reflected simulated chirp function described in Nason and Silverman, 1995. This function is a useful test function for evaluating wavelet shrinkage and time-scale analysis methodology as its frequency changes over time.

**Usage**

```r
simchirp(n=1024)
```

**Arguments**

- `n` The number of ordinates from which to sample the chirp signal.

**Details**

This function computes and returns the x and y coordinates of the reflected chirp function described in Nason and Silverman, 1995.

The formula for the reflected simulated chirp is *formula*

The chirp returned is a discrete sample on n equally spaced points between -1 and 1.

**Value**

A list with two components:

- `x` a vector of length n containing the ordered x ordinates of the chirp from -1 to 1.
- `y` a vector of length n containing the corresponding y ordinates of the chirp.
ssq

Compute sum of squares difference between two vectors

Description
Given two vectors, u and v, of length n, this function computes \( \sum_{i=1}^{n} (u_i - v_i)^2 \).

Usage
ssq(u, v)

Arguments
- u: One of the vectors
- v: The other of the vectors

Details
Description says all

Value
The sum of squares difference between the two vectors

Examples
ssq(c(1, 2), c(3, 4))
# [1] 8
Print out some basic information associated with an imwd object

Description

Prints out the number of levels, the dimensions of the original image from which the object came, the type of wavelet filter associated with the decomposition, the type of boundary handling.

Usage

## S3 method for class 'imwd'
summary(object, ...)

Arguments

- **object**  
  The object to print a summary about

- **...**  
  Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

imwd, threshold.imwd

Examples

m <- matrix(rnorm(32*32),nrow=32)
mimwd <- imwd(m)
summary(mimwd)
#UNcompressed image wavelet decomposition structure
#Levels:  5
#Original image was 32 x 32  pixels.
#Filter was: Daub cmpct on least asymm N=10
#Boundary handling: periodic
summary.imwdc

Print out some basic information associated with an imwdc object

Description

Prints out the number of levels, the dimensions of the original image from which the object came, the type of wavelet filter associated with the decomposition, the type of boundary handling.

Usage

## S3 method for class 'imwdc'
summary(object, ...)

Arguments

object

The object to print a summary about

...

Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

imwd, threshold.imwd

Examples

m <- matrix(rnorm(32*32),nrow=32)
imwd <- imwd(m)
mimwdc <- threshold(mimwd)
summary(mimwdc)
#Compressed image wavelet decomposition structure
#Levels:  5
#Original image was 32 x 32 pixels.
#Filter was:  Daub cmpct on least asymm N=10
#Boundary handling:  periodic
Use `summary()` on a `mwd` object.

**Description**

This function prints out more information about an `mwd` object in a nice human-readable form.

**Usage**

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

**Arguments**

- `object` An object of class `mwd` that you wish to print out more information.
- `...` Any other arguments.

**Value**

Nothing of any particular interest.

**RELEASE**

Version 3.9.6 (Although Copyright Tim Downie 1995-6)

**Note**

Prints out information about `mwd` objects in nice readable format.

**Author(s)**

Tim Downie

**See Also**

- `accessC.mwd`, `accessD.mwd`, `draw.mwd`, `mfirst.last`, `mfilter.select`, `mwd`, `mwd.object`, `mwr`, `plot.mwd`, `print.mwd`, `putC.mwd`, `putD.mwd`, `threshold.mwd`, `wd`, `wr.mwd`

**Examples**

```r
# Generate an mwd object.
#
tmp <- mwd(rnorm(32))
# # Now get Splus to use summary.mwd
# summary(tmp)
# Length of original: 32
```
# Levels: 4
# Filter was: Geronimo Multiwavelets
# Scaling fns: 2
# Wavelet fns: 2
# Prefilter: default
# Scaling factor: 2
# Boundary handling: periodic
# Transform type: wavelet
# Date: Tue Nov 16 13:55:26 GMT 1999

summary.wd

Print out some basic information associated with a wd object

Description

Prints out the number of levels, the length of the original vector from which the object came, the type of wavelet filter associated with the decomposition, the type of boundary handling, the transform type and the date of production.

Usage

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

Arguments

- `object` The object to print a summary about
- `...` Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wd
Examples

```r
vwd <- wd(1:8)
summary(vwd)
#Levels: 3
#Length of original: 8
#Filter was: Daub cmpct on least asymm N=10
#Boundary handling: periodic
#Transform type: wavelet
#Date: Mon Mar 8 21:30:32 2010
```

### summary.wd3D

Print out some basic information associated with a wd3D object

#### Description

Prints out the number of levels, the type of wavelet filter associated with the decomposition, and the date of production.

#### Usage

```r
## S3 method for class 'wd3D'
summary(object, ...)
```

#### Arguments

- `object` The object to print a summary about
- `...` Other arguments

#### Details

Description says all

#### Value

Nothing

#### Author(s)

G P Nason

#### See Also

`wd3D`
Examples

test.data.3D <- array(rnorm(8*8*8), dim=c(8,8,8))
tdwd3D <- wd3D(test.data.3D)
summary(tdwd3D)
#Levels: 3
#Filter number was: 10
#Filter family was: DaubLeAsymm
#Date: Mon Mar  8 21:48:00 2010

summary.wp

Print out some basic information associated with a wp object

Description

Prints out the number of levels, the length of the original vector from which the object came, the type of wavelet filter associated with the decomposition.

Usage

## S3 method for class 'wp'
summary(object, ...)

Arguments

- **object**: The object to print a summary about
- **...**: Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wp

Examples

vwp <- wp(rnorm(32))
summary(vwp)
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
Print out some basic information associated with a wpst object

Description

Prints out the number of levels, the length of the original vector from which the object came, the type of wavelet filter associated with the decomposition, and the date of production.

Usage

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

Arguments

- **object**: The object to print a summary about
- **...**: Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

wpst

Examples

```r
vwpst <- wpst(rnorm(32))
summary(vwpst)
#Levels: 5
#Length of original: 32
#Filter was: Daub cmpct on least asymm N=10
#Date: Mon Mar 8 21:54:47 2010
```
summary.wst

Print out some basic information associated with a wst object

Description

Prints out the number of levels, the length of the original vector from which the object came, the type of wavelet filter associated with the decomposition, and the date of production.

Usage

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

Arguments

- `object`: The object to print a summary about
- `...`: Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

- `wst`

Examples

```r
vwst <- wst(rnorm(32))
summary(vwst)
# Levels: 5
# Length of original: 32
# Filter was: Daub cmpct on least asymm N=10
# Date: Mon Mar 8 21:56:12 2010
```
Print out some basic information associated with a wst2D object

Description

Prints out the number of levels, the dimensions of the original image from which the object came, the type of wavelet filter associated with the decomposition, and the date of production.

Usage

```r
## S3 method for class 'wst2D'
summary(object, ...)
```

Arguments

- `object`: The object to print a summary about
- `...`: Other arguments

Details

Description says all

Value

Nothing

Author(s)

G P Nason

See Also

`wst2D`

Examples

```r
m <- matrix(rnorm(32*32), nrow=32)
mwst2D <- wst2D(m)
summary(mwst2D)
# Levels: 5
# Length of original: 32 x 32
# Filter was: Daub cmpct on least asym N=10
# Date: Mon Mar  8 21:57:55 2010
```
support

Returns support of compactly supported wavelets.

Description

Returns the support for compactly supported wavelets. This information is useful for drawing wavelets for annotating axes.

Usage

support(filter.number=10, family="DaubLeAsymm", m=0, n=0)

Arguments

- filter.number: The member index of a wavelet within the family. For Daubechies’ compactly supported wavelet this is the number of vanishing moments which is related to the smoothness. See filter.select for more information on the wavelets.
- family: The family of wavelets. See filter.select for more information on the wavelets.
- m: Optional scale value (in usual wavelet terminology this is j)
- n: Optional translation value (in usual wavelet terminology, this is k)

Details

It is useful to know the support of a wavelet when drawing it to annotate labels. Other functions, such as wavelet density estimation (CWavDE), also use this information.

Value

A list with the following components (each one is a single numeric value)

- lh: Left hand support of the wavelet with scale m and translation n. These values change as m and n (although when m=0 the function confusingly returns the next coarser wavelet where you might expect it to return the mother. The mother is indexed by m=-1)
- rh: As lh but returns the rh end.
- psi.lh: left hand end of the support interval for the mother wavelet (remains unchanged no matter what m or n are)
- psi.rh: right hand end of the support interval for the mother wavelet (remains unchanged no matter what m or n are)
- phi.lh: left hand end of the support interval for the father wavelet (remains unchanged no matter what m or n are)
- phi.rh: right hand end of the support interval for the father wavelet (remains unchanged no matter what m or n are)
**Author(s)**

G P Nason

**See Also**

CWavDE, draw.default, filter.select

**Examples**

```r
# What is the support of a Haar wavelet?
#
support(filter.number=1, family="DaubExPhase", m=0, n=0)
#$lh
# [1] 0
# # rh
# [1] 2
# # psi.lh
# [1] 0
# # psi.rh
# [1] 1
# # phi.lh
# [1] 0
# # phi.rh
# [1] 1
# # So the mother and father wavelet have support [0,1]
#
```

---

**sure**

*Computes the minimum of the SURE thresholding function*

**Description**


**Usage**

`sure(x)`
Arguments

x Vector of (normalized) wavelet coefficients. Coefficients should be supplied divided by their standard deviation, or some robust measure of scale

Details

SURE is a method for unbiasedly estimating the risk of an estimator. Stein (1981) showed that for a nearly arbitrary, nonlinear biased estimator, one can estimate its loss unbiasedly. See the Donoho and Johnstone, 1995 for further references and explanation. This function minimizes formula (11) from that paper.

Value

The absolute value of the wavelet coefficient that minimizes the SURE criteria

Author(s)

G P Nason

See Also

threshold

Examples

# Let's create "pretend" vector of wavelet coefficients contaminated with # "noise".
# v <- c(0.1, -0.2, 0.3, -0.4, 0.5, 99, 12, 6)
# Now, what's sure of this?
# sure(v)
# # [1] 0.5
# # I.e. the large significant coefficients are 99, 12, 6 and the noise is # anything less than this in abs value. So sure(v) is a good point to threshold # at.

Description

A 512x512 matrix. Each entry of the matrix contains an image intensity value.
Usage

data(teddy)

Format

A 512x512 matrix. Each entry of the matrix contains an image intensity value. The whole matrix represents an image of a teddy bear’s picnic.

Author(s)

G P Nason

Source

Taken by Guy Nason.

Examples

# This command produces the image seen above.
# # image(teddy)
#

test.dataCT

Description

This function evaluates the "blocks", "bumps", "heavisine" and "doppler" test functions of Donoho & Johnstone (1994b) and the piecewise polynomial test function of Nason & Silverman (1994). The function also generates data sets consisting of the specified function plus uncorrelated normally distributed errors.

Usage

test.dataCT(type = "ppoly", n = 512, signal = 1, rsnr = 7, plotfn = FALSE)

Arguments

type Test function to be computed. Available types are "ppoly" (piecewise polynomial), "blocks", "bumps", "heavi" (heavisine), and "doppler".

n Number of equally spaced data points on which the function is evaluated.

signal Scaling parameter; the function will be scaled so that the standard deviation of the data points takes this value.

rsnr Root signal-to-noise ratio. Specifies the ratio of the standard deviation of the function to the standard deviation of the simulated errors.

plotfn If plotfn=TRUE, then the test function and the simulated data set are plotted
Value
A list with the following components:

- **x**: The points at which the test function is evaluated.
- **y**: The values taken by the test function.
- **ynoise**: The simulated data set.
- **type**: The type of function generated, identical to the input parameter type.
- **rsnr**: The root signal-to-noise ratio of the simulated data set, identical to the input parameter rsnr.

Side effects
If `plotfn=T`, the test function and data set are plotted.

RELEASE
Part of the CThresh addon to WaveThresh. Copyright Stuart Barber and Guy Nason 2004.

Author(s)
Stuart Barber

---

threshold, Threshold coefficients

Description
Modify coefficients by thresholding or shrinkage.
This function is generic.
Particular methods exist for the following objects:

- **wd object** the `threshold.wd` function is used;
- **imwd object** the `threshold.imwd` function is used;
- **imwdc object** the `threshold.imwdc` function is used;
- **irrgwd object** the `threshold.irrgwd` function is used;
- **wd3D object** the `threshold.wd3D` function is used;
- **wp object** the `threshold.wp` function is used;
- **wst object** the `threshold.wst` function is used.

Usage
threshold(...)
threshold.imwd

Arguments

See individual help pages for details.

Details

See individual method help pages for operation and examples.

Value

Usually a copy of the input object but containing thresholded or shrunk coefficients.

RELEASE

Version 2 Copyright Guy Nason 1993

Author(s)

G P Nason

See Also

imwd.object, imwdc.object, irregwd.object, threshold.imwd, threshold.imwdc, threshold.irregwd, threshold.wd, threshold.wd3D, threshold.wp, threshold.wst.wd.object, wd3D.object, wp.object, wst.object.

threshold.imwd

Threshold two-dimensional wavelet decomposition object

Description

This function provides various ways to threshold a imwd class object.

Usage

## S3 method for class 'imwd'
threshold(imwd, levels = 3:(nlevelsWT(imwd) - 1), type = "hard", policy = "universal", by.level = FALSE, value = 0, dev = var, verbose = FALSE, return.threshold = FALSE, compression = TRUE, Q = 0.05, ...)

Arguments

imwd

The two-dimensional wavelet decomposition object that you wish to threshold.

levels

a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the imwd object supplied. This is usually any integer from 0 to nlevelsWT(wd)-1 inclusive. Only the levels in this vector contribute to the computation of the threshold and its application. (except for the fdr policy).
type determines the type of thresholding this can be "hard" or "soft".

classic selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are: "universal", "manual", "fdr", "probability". The policies are described in detail below.

by.level If FALSE then a global threshold is computed on and applied to all scale levels defined in levels. If TRUE a threshold is computed and applied separately to each scale level.

value This argument conveys the user supplied threshold. If the policy="manual" then value is the actual threshold value; if policy="probability" then value conveys the the user supplied quantile level.

dev this argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the var() function. A popular, useful and robust alternative is the madmad function.

verbose if TRUE then the function prints out informative messages as it progresses.

return.threshold If this option is TRUE then the actual value of the threshold is returned. If this option is FALSE then a thresholded version of the input is returned.

compression If this option is TRUE then this function returns a compressed two-dimensional wavelet transform object of class imwdc. This can be useful as the resulting object will be smaller than if it was not compressed. The compression makes use of the fact that many coefficients in a thresholded object will be exactly zero. If this option is FALSE then a larger imwd object will be returned.

Q Parameter for the false discovery rate "fdr" policy.

... any other arguments

Details

This function thresholds or shrinks wavelet coefficients stored in a imwd object and by default returns the coefficients in a modified imwdc object. See the seminal papers by Donoho and Johnstone for explanations about thresholding. For a gentle introduction to wavelet thresholding (or shrinkage as it is sometimes called) see Nason and Silverman, 1994. For more details on each technique see the descriptions of each method below

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of an image is very sparse, the wavelet transform of noise is not (in particular, if the noise is iid Gaussian then so if the noise contained in the wavelet coefficients). Thus, since the image gets concentrated in few wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to true image) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no image coefficients "stick up" above the noise.

There are many components to a successful thresholding procedure. Some components have a larger effect than others but the effect is not the same in all practical data situations. Here we give some rough practical guidance, although you must refer to the papers below when using a
particular technique. You cannot expect to get excellent performance on all signals unless you fully understand the rationale and limitations of each method below. I am not in favour of the "black-box" approach. The thresholding functions of WaveThresh3 are not a black box: experience and judgement are required!

Some issues to watch for:

levels The default of levels = 3:(wd$nlevelsWT - 1) for the levels option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not in WaveThresh).

Secondly the levels argument computes and applies the threshold at the levels specified in the levels argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the threshold.imwd function twice. Once (with levels set equal to nlevelsWT(wd)-1) and with return.threshold=TRUE to return the threshold computed on the finest scale and then apply the threshold function with the manual option supplying the value of the previously computed threshold as the value options.

Note that the fdr policy does its own thing.

by.level for a wd object which has come from data with noise that is correlated then you should have a threshold computed for each resolution level. See the paper by Johnstone and Silverman, 1997.

Value

An object of class imwdc if the compression option above is TRUE, otherwise a imwd object is returned. In either case the returned object contains the thresholded coefficients. Note that if the return.threshold option is set to TRUE then the threshold values will be returned rather than the thresholded object.

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Note

This section gives a brief description of the different thresholding policies available. For further details see the associated papers. If there is no paper available then a small description is provided here. More than one policy may be good for problem, so experiment! They are arranged here in alphabetical order:

manual specify a user supplied threshold using value to pass the value of the threshold. The value argument should be a vector. If it is of length 1 then it is replicated to be the same length as the levels vector, otherwise it is repeated as many times as is necessary to be the levels vector’s length. In this way, different thresholds can be supplied for different levels. Note that the by.level option has no effect with this policy.

probability The probability policy works as follows. All coefficients that are smaller than the value of the quantile of the coefficients are set to zero. If by.level is false, then the quantile is computed for all coefficients in the levels specified by the "levels" vector; if by.level is true, then each level’s quantile is estimated separately. The probability policy is pretty stupid - do not use it.

universal See Donoho and Johnstone, 1995.

Author(s)

G P Nason

References

The FDR code segments were kindly donated by Felix Abramovich.

See Also

imwd, imwd.object, imwdc.object, threshold.

Examples

```r
# Let's use the lennon test image
# data(lennon)
## Not run: image(lennon)
# Now let's do the 2D discrete wavelet transform
# lwd <- imwd(lennon)
# Let's look at the coefficients
# ## Not run: plot(lwd)
# Now let's threshold the coefficients
# lwdT <- threshold(lwd)
# And let's plot those the thresholded coefficients
# ## Not run: plot(lwdT)
# Note that the only remaining coefficients are down in the bottom left hand corner of the plot. All the others (black) have been set to zero (i.e. thresholded).
```
Description

This function provides various ways to threshold a imwdc class object.

Usage

## S3 method for class 'imwdc'
threshold(imwdc, verbose=FALSE, ...)

Arguments

- **imwdc**: The two-dimensional compressed wavelet decomposition object that you wish to threshold.
- **verbose**: if TRUE then the function prints out informative messages as it progresses.
- **...**: other arguments passed to the threshold.imwd function to control the thresholding characteristics such as policy, type of thresholding etc.

Details

This function performs exactly the same function as threshold.imwd except it accepts objects of class imwdc rather than imwd. Indeed, this function physically calls the threshold.imwd function after using the uncompress function to convert the input imwdc object into a imwd object.

Value

An object of class imwdc if the compression option is supplied and set to TRUE, otherwise a imwd object is returned. In either case the returned object contains the thresholded coefficients. Note that if the return.threshold option is set to TRUE then the threshold values will be returned rather than the thresholded object.

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Author(s)

G P Nason

References

The FDR code segments were kindly donated by Felix Abramovich.

See Also

imwd, imwd.object, imwdc.object, threshold, uncompress.
threshold.irregwd

**Examples**

```r
# See examples in \code{\link{threshold.imwd}}.
```

**threshold.irregwd**  
*hold irregularly spaced wavelet decomposition object*

**Description**

This function provides various ways to threshold a *irreg* class object.

**Usage**

```r
## S3 method for class 'irregwd'
threshold(irregwd, 
    levels = 3:(nlevelsWT(wd) - 1), type = "hard", policy = "universal", 
    by.level = FALSE, value = 0, dev = var, boundary = FALSE, 
    verbose = FALSE, return.threshold = FALSE, 
    force.sure=FALSE, cvtol = 0.01, Q = 0.05, alpha=0.05, ...)
```

**Arguments**

- `irregwd`  
  The irregularly spaced wavelet decomposition object that you wish to threshold.

- `levels`  
  a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the *irreg* object supplied. This is usually any integer from 0 to `nlevelsWT(irregwd)`-1 inclusive. Only the levels in this vector contribute to the computation of the threshold and its application.

- `type`  
  determines the type of thresholding this can be "hard" or "soft".

- `policy`  
  selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are: "universal", "LSuniversal", "sure", "cv", "fdr", "op1", "op2", "manual", "mannum", "probability". A description of the policies can be obtained by clicking on the above links.

- `by.level`  
  If FALSE then a global threshold is computed on and applied to all scale levels defined in levels. If TRUE a threshold is computed and applied separately to each scale level.

- `value`  
  This argument conveys the user supplied threshold. If the `policy="manual"` then value is the actual threshold value.

- `dev`  
  this argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the `var()` function. A popular, useful and robust alternative is the `mad()` function.
threshold.irregwd

boundary If this argument is TRUE then the boundary bookeeping values are included for thresholding, otherwise they are not.
verbose if TRUE then the function prints out informative messages as it progresses.
return.threshold If this option is TRUE then the actual value of the threshold is returned. If this option is FALSE then a thresholded version of the input is returned.
force.sure If TRUE then the SURE threshold is computed on a vector even when that vector is very sparse. If FALSE then the normal SUREshrink procedure is followed whereby the universal threshold is used for sparse vectors of coefficients.
cvtol Parameter for the cross-validation "cv" policy.
Q Parameter for the false discovery rate "fdr" policy.
alpha Parameter for Ogden and Parzen’s first "op1" and "op2" policies.
... other arguments

Details

This function thresholds or shrinks wavelet coefficients stored in an irregwd object and returns the coefficients in a modified irregwd object. The thresholding step is an essential component of denoising.

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of signal is very sparse, the wavelet transform of noise is not (in particular, if the noise is iid Gaussian then so if the noise contained in the wavelet coefficients). Thus since the signal gets concentrated in the wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to signal) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no signal "sticks up" above the noise.

For thresholding of an irregularly spaced wavelet decomposition things are a little different. The original data are irregularly spaced (i.e. [x,y] where the xi are irregularly spaced) and even if one assumes iid error on the original data once this has been interpolated to a grid by the makegrid function the interpolated data values are not independent. The irregwd function computes the wavelet transform of the interpolated data but also computes the variance of each coefficient using a fast transform. This variance information is stored in the c component of irregwd objects and this function, threshold.irregwd, makes use of this variance information when thresholding each coefficient. For more details see Kovac and Silverman, 2000

Some issues to watch for:

levels The default of levels = 3:(wd$nlevelsWT - 1) for the levels option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not yet in WaveThresh).
Secondly the levels argument computes and applies the threshold at the levels specified in the levels argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the threshold.wd function twice. Once (with levels set equal to \( n \) levels \( T(wd) - 1 \)) and with return.threshold=TRUE to return the threshold computed on the finest scale and then apply the threshold function with the manual option supplying the value of the previously computed threshold as the value options.

by.level for a \( wd \) object which has come from data with noise that is correlated then you should have a threshold computed for each resolution level. See the paper by Johnstone and Silverman, 1997.

Value

An object of class \texttt{irregwd}. This object contains the thresholded wavelet coefficients. Note that if the return.threshold option is set to \texttt{TRUE} then the threshold values will be returned rather than the thresholded object.

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Author(s)

Arne Kovac

See Also

\texttt{makegrid, irregwd, irregwd} object, \texttt{accessc}.

Examples

\begin{verbatim}
# # See main examples of these functions in the help to makegrid #
\end{verbatim}

\begin{verbatim}
threshold.mwd
Use threshold on an mwd object.
\end{verbatim}

Description

Applies hard or soft thresholding to multiple wavelet decomposition object \texttt{mwd.object}.
Usage

```r
## S3 method for class 'mwd'
threshold(mwd, levels = 3:(nlevelsWT(mwd) - 1), type = "hard",
          policy = "universal", boundary = FALSE, verbose = FALSE,
          return.threshold = FALSE, threshold = 0, cvtol = 1e-09,
          robust = TRUE, return.chisq = FALSE,
          bivariate = TRUE, ...)
```

Arguments

- **mwd**: The multiple wavelet decomposition object that you wish to threshold.
- **levels**: a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the `mwd` object supplied. This is usually any integer from 0 to `nlevelsWT(wd)-1` inclusive. Only the levels in this vector contribute to the computation of the threshold and its application.
- **type**: determines the type of thresholding this can be "hard" or "soft".
- **policy**: selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are "universal", "manual", "single". The policies are described in detail below.
- **boundary**: If this argument is `TRUE` then the boundary bookkeeping values are included for thresholding, otherwise they are not.
- **verbose**: if `TRUE` then the function prints out informative messages as it progresses.
- **return.threshold**: If this option is `TRUE` then the actual value of the threshold is returned. If this option is `FALSE` then a thresholded version of the input is returned.
- **threshold**: This argument conveys the user supplied threshold. If the `policy="manual"` then value is the actual threshold value. Any other policy means that the threshold value is ignored.
- **cvtol**: The tolerance for what constitutes a singular variance matrix. If smallest eigenvalue of the estimated variance matrix is less than `cvtol` then it is assumed to be singular and no thresholding is done at that level. Note: do not confuse `cvtol` with `cvtol` an argument in `threshold.wd`.
- **robust**: If `TRUE` the variance matrix at each level is estimated using a robust method (mad) otherwise it is estimated using var().
- **return.chisq**: If `TRUE` the vector of values to be thresholded is returned. These values are a quadratic form of each coefficient vector, and under normal assumptions the noise component will have a chi-squared distribution (see Downie and Silverman 1996).
- **bivariate**: this line is in construction
- **...**: any other arguments
Details

Thresholding modifies the coefficients within a \texttt{mwd.object}. The modification can be performed either with a "hard" or "soft" thresholding selected by the type argument.

Unless policy="single", the following method is applied. The columns of \texttt{mwd$D} are taken as coefficient vectors \( D_{j,k} \). From these \( \chi_{j,k}^2 = D_{j,k} \cdot V_j^{-1} \). \( D_{j,k} \) is computed, where \( V_j^{-1} \) is the inverse of the estimated variance of the coefficient vectors in that level (j). \( \chi_{j,k}^2 \) is a positive scalar which is to be thresholded in a similar manner to univariate hard or soft thresholding. To obtain the new values of \( D_{j,k} \) shrink the vector by the same proportion as was the corresponding \( \chi_{j,k}^2 \) term. i

Value

An object of class \texttt{mwd}. This object contains the thresholded wavelet coefficients. Note that if the \texttt{return.threshold} option is set to TRUE then the threshold values will be returned, or if \texttt{return.chisq} the vector of values to be thresholded will be returned, rather than the thresholded object.

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Note

POLICIES

- 	exttt{single} If policy="single" then univariate thresholding is applied to each element of D as in (Strela et al 1999).
- 	exttt{universal} The universal threshold is computed using \( 2\log(n) \) (See Downie & Silverman 1996) where \( n \) is the number of coefficient vectors to be thresholded.
- 	exttt{manual} The "manual" policy is simple. You supply a \texttt{threshold} value to the \texttt{threshold} argument and hard or soft thresholding is performed using that value

Author(s)

Tim Downie

See Also

\texttt{accessC.mwd, accessD.mwd, draw.mwd, mfirst.last, mfilter.select, mwd, mwd.object, mwr, plot.mwd, print.mwd, putC.mwd, putD.mwd, summary.mwd, wd, wr.mwd}.

Examples

```r
# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Generate some noisy data
```
Threshold (DWT) wavelet decomposition object

Threshold (DWT) wavelet decomposition object

Description

This function provides various ways to threshold a \texttt{wd} class object.

Usage

```r
## S3 method for class 'wd'
threshold(wd, levels = 3:(nlevelsWT(wd) - 1), type = "soft", policy = "sure",
by.level = FALSE, value = 0, dev = madmad, boundary = FALSE, verbose = FALSE,
return.threshold = FALSE, force.sure = FALSE, cvtol = 0.01,
cvmaxits=500, Q = 0.05, OP1alpha = 0.05,
alPHA = 0.5, beta = 1, C1 = NA, C2 = NA, C1.start = 100,
al.check=TRUE, ...)
```
Arguments

wd  The DWT wavelet decomposition object that you wish to threshold.
levels  a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the wd object supplied. This is usually any integer from 0 to nlevelsWT(wd)-1 inclusive. Only the levels in this vector contribute to the computation of the threshold and its application.
type  determines the type of thresholding this can be "hard" or "soft".
policy  selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are: "universal", "LSuniversal", "sure", "BayesThresh", "cv", "fdr", "op1", "op2", "manual", "mannum" and "probability". The policies are described in detail below.
by.level  If FALSE then a global threshold is computed on and applied to all scale levels defined in levels. If TRUE a threshold is computed and applied separately to each scale level.
value  This argument conveys the user supplied threshold. If the policy="manual" then value is the actual threshold value; if the policy="mannum" then value conveys the total number of ordered coefficients kept (from the largest); if policy="probability" then value conveys the the user supplied quantile level.
dev  this argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the var() function. A popular, useful and robust alternative is the madmad function.
boundary  If this argument is TRUE then the boundary bookeeping values are included for thresholding, otherwise they are not.
verbose  if TRUE then the function prints out informative messages as it progresses.
return.threshold  If this option is TRUE then the actual value of the threshold is returned. If this option is FALSE then a thresholded version of the input is returned.
force.sure  If TRUE then the sure threshold is computed on a vector even when that vector is very sparse. If FALSE then the normal SUREshrink procedure is followed whereby the universal threshold is used for sparse vectors of coefficients.
cvtol  Parameter for the cross-validation "cv" policy.
cvmaxits  Maximum number of iterations allowed for the cross-validation "cv" policy.
Q  Parameter for the false discovery rate "fdr" policy.
OP1alpha  Parameter for Ogden and Parzen’s first "op1" and "op2" policies.
alpha  Parameter for BayesThresh "BayesThresh" policy.
beta  Parameter for BayesThresh "BayesThresh" policy.
C1  Parameter for BayesThresh "BayesThresh" policy.
C2  Parameter for BayesThresh "BayesThresh" policy.
C1.start  Parameter for BayesThresh "BayesThresh" policy.
If TRUE then the function checks that the levels are in ascending order. If they are not then this can be an indication that the default level arguments are not appropriate for this data set (wd object). However, a strange order might be appropriate for some reason if deliberately set, so setting this argument equal to FALSE turns off the check and warning.

\[ \text{any other arguments} \]

**Details**

This function thresholds or shrinks wavelet coefficients stored in a \texttt{wd} object and returns the coefficients in a modified \texttt{wd} object. See the seminal papers by Donoho and Johnstone for explanations about thresholding. For a gentle introduction to wavelet thresholding (or shrinkage as it is sometimes called) see Nason and Silverman, 1994. For more details on each technique see the descriptions of each method below.

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of signal is very sparse, the wavelet transform of noise is not (in particular, if the noise is iid Gaussian then so if the noise contained in the wavelet coefficients). Thus since the signal gets concentrated in the wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to signal) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no signal "sticks up" above the noise.

There are many components to a successful thresholding procedure. Some components have a larger effect than others but the effect is not the same in all practical data situations. Here we give some rough practical guidance, although you must refer to the papers below when using a particular technique. You cannot expect to get excellent performance on all signals unless you fully understand the rationale and limitations of each method below. I am not in favour of the "black-box" approach. The thresholding functions of WaveThresh3 are not a black box: experience and judgement are required!

Some issues to watch for:

**levels** The default of \texttt{levels = 3:(wd$\text{nlevelsWT} - 1)} for the \texttt{levels} option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not in WaveThresh).

Secondly the levels argument computes and applies the threshold at the levels specified in the \texttt{levels} argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the \texttt{threshold.wd} function twice. Once (with levels set equal to \texttt{\text{nlevelsWT}(wd)-1}) and with \texttt{return.threshold=TRUE} to return the threshold computed on the finest scale and then apply...
the threshold function with the manual option supplying the value of the previously computed
threshold as the value options.

Thirdly, if you apply wavelet shrinkage to a small data set then you need to ensure you’ve
chosen the levels argument appropriately. For example, if your original data was of length
8, then the associated wd wavelet decomposition object will only have levels 0, 1 and 2. So,
the default argument for levels (starting at 3 and higher) will almost certainly be wrong. The
code now warns for these situations.

by.level  for a wd object which has come from data with noise that is correlated then you should have
a threshold computed for each resolution level. See the paper by Johnstone and Silverman,
1997.

Value

An object of class wd. This object contains the thresholded wavelet coefficients. Note that if the
return.threshold option is set to TRUE then the threshold values will be returned rather than the
thresholded object.

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Note

POLICIES This section gives a brief description of the different thresholding policies available. For
further details see the associated papers. If there is no paper available then a small description is
provided here. More than one policy may be good for problem, so experiment! They are arranged
here in alphabetical order:

and Fanis Sapatinas.

cv  See Nason, 1996.


LSuniversal  See Nason, von Sachs and Kroisandt, 1998. This is used for smoothing of a wavelet
periodogram and shouldn’t be used generally.

manual  specify a user supplied threshold using value to pass the value of the threshold. The value
argument should be a vector. If it is of length 1 then it is replicated to be the same length as
the levels vector, otherwise it is repeated as many times as is necessary to be the levels
vector’s length. In this way, different thresholds can be supplied for different levels. Note that
the by.level option has no effect with this policy.

mannum  You decided how many of the largest (in absolute value) coefficients that you want to
keep and supply this number in value.

op1  See Ogden and Parzen, 1996. Contributed by Todd Ogden.


probability  The probability policy works as follows. All coefficients that are smaller than the
valueth quantile of the coefficients are set to zero. If by.level is false, then the quantile is
computed for all coefficients in the levels specified by the "levels" vector; if by.level is true,
then each level’s quantile is estimated separately. The probability policy is pretty stupid - do
not use it.
sure  See Donoho and Johnstone, 1994.
universal  See Donoho and Johnstone, 1995.

Author(s)
G P Nason

References
Various code segments detailed above were kindly donated by Felix Abramovich, Theofanis Sapatinas and Todd Ogden.

See Also
wd, wd.object, wr, wr.wd, threshold.

Examples

```r
# Generate some test data
#
#test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Generate some noisy data
#
ynoise <- test.data + rnorm(512, sd=0.1)
#
# Plot it
#
## Not run: ts.plot(ynoise)
#
# Now take the discrete wavelet transform
# N.b. I have no idea if the default wavelets here are appropriate for
# this particular examples.
#
ynd <- wd(ynoise)
## Not run: plot(ynd)
#
# Now do thresholding. We'll use a universal policy,
# and madmad deviance estimate on the finest
# coefficients and return the threshold. We'll also get it to be verbose
# so we can watch the process.
#
yndT1 <- threshold(ynd, policy="universal", dev=madmad,
levels= nlevelsWT(ynd)-1, return.threshold=TRUE,
verbose=TRUE)
# threshold.wd:
# Argument checking
# Universal policy...All levels at once
# Global threshold is: 0.328410967430135
```
# Why is this the threshold? Well in this case n=512 so \(\sqrt{2\log(n)}\),
# the universal threshold, 
# is equal to 3.53223. Since the noise is about 0.1 (because that's what 
# we generated it to be) the threshold is about 0.353. 
# Now let's apply this threshold to all levels in the noisy wavelet object 
# ynwdT1obj <- threshold(ynwd, policy="manual", value=ynwdT1, 
# levels=0:(nlevelsWT(ynwd)-1))
# # And let's plot it 
# ## Not run: plot(ynwdT1obj) 
# # You'll see that a lot of coefficients have been set to zero, or shrunk. 
# # Let's try a Bayesian examples this time!
# # ynwdT2obj <- threshold(ynwd, policy="BayesThresh")
# # And plot the coefficients 
# ## Not run: plot(ynwdT2obj)
# # Let us now see what the actual estimates look like 
# ywr1 <- wr(ynwdT1obj) ywr2 <- wr(ynwdT2obj)
# # Here's the estimate using universal thresholding 
# ## Not run: ts.plot(ywr1)
# # Here's the estimate using BayesThresh 
# ## Not run: ts.plot(ywr2)

threshold.wd3D

### Description

This function provides various ways to threshold a \texttt{wd3D} class object.

### Usage

```r
## S3 method for class 'wd3D'
threshold(wd3D, levels = 3:(nlevelsWT(wd3D) - 1), type = "hard", policy = "universal", by.level = FALSE, value = 0, dev = var, verbose = FALSE, return.threshold = FALSE, ...)
```
Arguments

wd3D  
The 3D DWT wavelet decomposition object that you wish to threshold.

levels  
a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the wd3D object supplied. This is usually any integer from 0 to nlevelsWT(wd3D)-1 inclusive. Only the levels in this vector contribute to the computation of the threshold and its application.

type  
determines the type of thresholding this can be "hard" or "soft".

policy  
selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are: "universal" and "manual". The policies are described in detail below.

by.level  
If FALSE then a global threshold is computed on and applied to all scale levels defined in levels. If TRUE a threshold is computed and applied separately to each scale level.

value  
This argument conveys the user supplied threshold. If the policy="manual" then value is the actual threshold value.

dev  
this argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the var() function. A popular, useful and robust alternative is the madmad function.

verbose  
if TRUE then the function prints out informative messages as it progresses.

return.threshold  
If this option is TRUE then the actual value of the threshold is returned. If this option is FALSE then a thresholded version of the input is returned.

...  
any other arguments

Details

This function thresholds or shrinks wavelet coefficients stored in a wd3D object and returns the coefficients in a modified wd3D object. See the seminal papers by Donoho and Johnstone for explanations about thresholding. For a gentle introduction to wavelet thresholding (or shrinkage as it is sometimes called) see Nason and Silverman, 1994. For more details on each technique see the descriptions of each method below.

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of signal is very sparse, the wavelet transform of noise is not (in particular, if the noise is iid Gaussian then so if the noise contained in the wavelet coefficients). Thus since the signal gets concentrated in the wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to signal) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no signal "sticks up" above the noise.

There are many components to a successful thresholding procedure. Some components have a larger effect than others but the effect is not the same in all practical data situations. Here we give some rough practical guidance, although you must refer to the papers below when using a particular technique. You cannot expect to get excellent performance on all signals unless you
fully understand the rationale and limitations of each method below. I am not in favour of the "black-box" approach. The thresholding functions of WaveThresh3 are not a black box: experience and judgement are required!

Some issues to watch for:

levels The default of levels = 3:(wd$nlevelsWT - 1) for the levels option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not in WaveThresh).

Secondly the levels argument computes and applies the threshold at the levels specified in the levels argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the threshold.wd function twice. Once (with levels set equal to nlevelsWT(wd)-1 and with return.threshold=TRUE) to return the threshold computed on the finest scale and then apply the threshold function with the manual option supplying the value of the previously computed threshold as the value options.

by.level for a wd object which has come from data with noise that is correlated then you should have a threshold computed for each resolution level. See the paper by Johnstone and Silverman, 1997.

Value

An object of class wd3D. This object contains the thresholded wavelet coefficients. Note that if the return.threshold option is set to TRUE then the threshold values will be returned rather than the thresholded object.

RELEASE

Version 3.9.6 Copyright Guy Nason 1997.

Note

POLICIES

This section gives a brief description of the different thresholding policies available. For further details see the associated papers. If there is no paper available then a small description is provided here. More than one policy may be good for problem, so experiment! They are arranged here in alphabetical order:

manual specify a user supplied threshold using value to pass the value of the threshold. The value argument should be a vector. If it is of length 1 then it is replicated to be the same length as the levels vector, otherwise it is repeated as many times as is necessary to be the levels
vector's length. In this way, different thresholds can be supplied for different levels. Note that
the by.level option has no effect with this policy.

universal  See Donoho and Johnstone, 1995.

Author(s)
G P Nason

See Also
threshold, accessD.wd3D, print.wd3D, putD.wd3D, putDwd3Dcheck, summary.wd3D, threshold.wd3D,
wd3D.object, wr3D.

Examples

# Generate some test data
#
test.data <- array(rnorm(8*8*8), dim=c(8,8,8))
testwd3D <- wd3D(test.data)
#
# Now let's threshold
#
testwd3DT <- threshold(testwd3D, levels=1:2)
#
# That's it, one can apply wr3D now to reconstruct
# if you like!
#

---

threshold.wp  

Threshold wavelet packet decomposition object

Description

This function provides various ways to threshold a wp class object.

Usage

## S3 method for class 'wp'
threshold(wp, levels = 3:(nlevelsWT(wp) - 1), dev = madmad,
policy = "universal", value = 0, by.level = FALSE, type = "soft",
verbose = FALSE, return.threshold = FALSE, cvtol = 0.01, cvnorm = l2norm,
add.history = TRUE, ...)
Arguments

wp
The wavelet packet object that you wish to threshold.

levels
a vector of integers which determines which scale levels are thresholded in the decomposition. Each integer in the vector must refer to a valid level in the wd object supplied. This is usually any integer from 0 to nlevelsWT(wp)-1 inclusive. Only the levels in this vector contribute to the computation of the threshold and its application.

policy
selects the technique by which the threshold value is selected. Each policy corresponds to a method in the literature. At present the different policies are: "universal" and "manual". The policies are described in detail below.

by.level
If FALSE then a global threshold is computed on and applied to all scale levels defined in levels. If TRUE a threshold is computed and applied separately to each scale level.

value
This argument conveys the user supplied threshold. If the policy="manual" then value is the actual threshold value.

dev
this argument supplies the function to be used to compute the spread of the absolute values coefficients. The function supplied must return a value of spread on the variance scale (i.e. not standard deviation) such as the var() function. A popular, useful and robust alternative is the madmad function.

type
determines the type of thresholding this can be "hard" or "soft".

verbose
if TRUE then the function prints out informative messages as it progresses.

return.threshold
If this option is TRUE then the actual value of the threshold is returned. If this option is FALSE then a thresholded version of the input is returned.

cvtol
Not used, but reserved for future use

cvnorm
Not used, but reserved for future use

add.history
if TRUE then a history statement is added to the object for displaying.

... any other arguments

Details

This function thresholds or shrinks wavelet coefficients stored in a wp object and returns the coefficients in a modified wp object. See the seminal papers by Donoho and Johnstone for explanations about thresholding. For a gentle introduction to wavelet thresholding (or shrinkage as it is sometimes called) see Nason and Silverman, 1994. For more details on each technique see the descriptions of each method below.

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of signal is very sparse, the wavelet transform of noise is not (in particular, if the noise is iid Gaussian then so if the noise contained in the wavelet coefficients). Thus since the signal gets concentrated in the wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to signal) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no signal "sticks up" above the noise.
There are many components to a successful thresholding procedure. Some components have a larger effect than others but the effect is not the same in all practical data situations. Here we give some rough practical guidance, although you must refer to the papers below when using a particular technique. **You cannot expect to get excellent performance on all signals unless you fully understand the rationale and limitations of each method below.** I am not in favour of the "black-box" approach. The thresholding functions of WaveThresh3 are not a black box: experience and judgement are required!

Some issues to watch for:

**levels** The default of `levels = 3:(wd$nlevelsWT - 1)` for the `levels` option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not in WaveThresh).

Secondly the levels argument computes and applies the threshold at the levels specified in the `levels` argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the `threshold.wp` function twice. Once (with levels set equal to `nlevelsWT(wd)-1` and with `return.threshold=TRUE` to return the threshold computed on the finest scale and then apply the threshold function with the manual option supplying the value of the previously computed threshold as the value options.

**by.level** for a `wd` object which has come from data with noise that is correlated then you should have a threshold computed for each resolution level. See the paper by Johnstone and Silverman, 1997.

**Value**

An object of class `wp`. This object contains the thresholded wavelet coefficients. Note that if the `return.threshold` option is set to TRUE then the threshold values will be returned rather than the thresholded object.

**RELEASE**

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**Note**

**POLICIES**

This section gives a brief description of the different thresholding policies available. For further details see the associated papers. If there is no paper available then a small description is provided here. More than one policy may be good for problem, so experiment! They are arranged here in alphabetical order:
universal  See Donoho and Johnstone, 1995.

Author(s)
G P Nason

See Also
wp, wp.object, InvBasis, MaNoVe, threshold.

Examples

# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Generate some noisy data
#
ynoise <- test.data + rnorm(512, sd=0.1)
#
# Plot it
#
## Not run: ts.plot(ynoise)
#
# Now take the discrete wavelet packet transform
# N.b. I have no idea if the default wavelets here are appropriate for
# this particular examples.
#
ywtp <- wp(ynoise)
#
# Now do thresholding. We'll use a universal policy,
# and madmad deviance estimate on the finest
# coefficients and return the threshold. We'll also get it to be verbose
# so we can watch the process.
#
ywtpT1 <- threshold(ywtp, policy="universal", dev=madmad)
#
# This is just another wp object. Is it sensible?
# Probably not as we have just thresholded the scaling function coefficients
# as well. So the threshold might be more sensibly computed on the wavelet
# coefficients at the finest scale and then this threshold applied to the
# whole wavelet tree??

threshold.wst  
Threshold (NDWT) packet-ordered non-decimated wavelet decomposition object
Description

This function provides various ways to threshold a wst class object

Usage

## S3 method for class 'wst'
threshold(wst, levels = 3:(nlevelsWT(wst) - 1), dev = madmad, policy =
"universal", value = 0, by.level = FALSE, type = "soft", verbose
= FALSE, return.threshold = FALSE, cvtol = 0.01, cvnorm = l2norm,
add.history = TRUE, ...)

Arguments

wst The packet ordered non-decimated wavelet decomposition object that you wish
to threshold.

levels a vector of integers which determines which scale levels are thresholded in the
decomposition. Each integer in the vector must refer to a valid level in the
wst object supplied. This is usually any integer from 0 to nlevelsWT(wst)-1
inclusive. Only the levels in this vector contribute to the computation of the
threshold and its application.

dev this argument supplies the function to be used to compute the spread of the
absolute values coefficients. The function supplied must return a value of spread
on the variance scale (i.e. not standard deviation) such as the var() function. A
popular, useful and robust alternative is the madmad function

policy selects the technique by which the threshold value is selected. Each policy cor-
responds to a method in the literature. At present the different policies are:
"universal", "LSuniversal", "sure", "cv", "manual". The policies are de-
scribed in detail below.

value This argument conveys the user supplied threshold. If the policy="manual"
then value is the actual threshold value.

by.level If FALSE then a global threshold is computed on and applied to all scale levels
deefined in levels. If TRUE a threshold is computed and applied separately to
each scale level.

type determines the type of thresholding this can be "hard" or "soft".

verbose if TRUE then the function prints out informative messages as it progresses.

return.threshold If this option is TRUE then the actual value of the threshold is returned. If this
option is FALSE then a thresholded version of the input is returned.

cvtol Parameter for the cross-validation "cv" policy.

cvnorm A function to compute the distance between two vectors. Two useful possibili-
ties are l2norm and linfnorm. Selection of different metrics causes the cross-
validation denoising method to optimize for different criteria.

add.history If TRUE then the thresholding operation details are add to the returned wst object.
This can be useful when later tracing how an object has been treated.

... any other arguments
Thresholding wavelet coefficients stored in a `wst` object and returns the coefficients in a modified `wst` object. The thresholding step is an essential component of denoising using the packet-ordered non-decimated wavelet transform. If the denoising is carried out using the `AvBasis` basis averaging technique then this software is an implementation of the Coifman and Donoho translation-invariant (TI) denoising. (Although it is the denoising technique which is translation invariant, not the packet ordered non-decimated transform, which is translation equivariant). However, the `threshold.wst` algorithm can be used in other denoising techniques in conjunction with the basis selection and inversion functions `MaNoVe` and `InvBasis`.

The basic idea of thresholding is very simple. In a signal plus noise model the wavelet transform of signal is very sparse, the wavelet transform of noise is not (in particular, if the noise is i.i.d. Gaussian then so if the noise contained in the wavelet coefficients). Thus since the signal gets concentrated in the wavelet coefficients and the noise remains "spread" out it is "easy" to separate the signal from noise by keeping large coefficients (which correspond to signal) and delete the small ones (which correspond to noise). However, one has to have some idea of the noise level (computed using the dev option in threshold functions). If the noise level is very large then it is possible, as usual, that no signal "sticks up" above the noise.

Many of the pragmatic comments for successful thresholding given in the help for `threshold.wd` hold true here: after all non-decimated wavelet transforms are merely organized collections of standard (decimated) discrete wavelet transforms. We reproduce some of the issues relevant to thresholding `wst` objects.

Some issues to watch for:

**levels**  The default of `levels = 3:(nlevelsWT(wd) - 1)` for the `levels` option most certainly does not work globally for all data problems and situations. The level at which thresholding begins (i.e. the given threshold and finer scale wavelets) is called the primary resolution and is unique to a particular problem. In some ways choice of the primary resolution is very similar to choosing the bandwidth in kernel regression albeit on a logarithmic scale. See Hall and Patil, (1995) and Hall and Nason (1997) for more information. For each data problem you need to work out which is the best primary resolution. This can be done by gaining experience at what works best, or using prior knowledge. It is possible to "automatically" choose a "best" primary resolution using cross-validation (but not yet in WaveThresh).

Secondly the levels argument computes and applies the threshold at the levels specified in the `levels` argument. It does this for all the levels specified. Sometimes, in wavelet shrinkage, the threshold is computed using only the finest scale coefficients (or more precisely the estimate of the overall noise level). If you want your threshold variance estimate only to use the finest scale coefficients (e.g. with universal thresholding) then you will have to apply the `threshold.wd` function twice. Once (with levels set equal to `nlevelsWT(wd)-1` and with `return.threshold=TRUE` to return the threshold computed on the finest scale and then apply the threshold function with the `manual` option supplying the value of the previously computed threshold as the value options.

**by.level**  for a `wd` object which has come from data with noise that is correlated then you should have a threshold computed for each resolution level. See the paper by Johnstone and Silverman, 1997.
Value

An object of class \texttt{wst}. This object contains the thresholded wavelet coefficients. Note that if the \texttt{return.threshold} option is set to \texttt{TRUE} then the threshold values will be returned rather than the thresholded object.

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Note

This section gives a brief description of the different thresholding policies available. For further details see the associated papers. If there is no paper available then a small description is provided here. More than one policy may be good for problem, so experiment! Some of the policies here were specifically adapted to the \texttt{wst.object} but some weren’t so beware. They are arranged here in alphabetical order:

\texttt{cv} See Nason, 1996.

\texttt{LSuniversal} See Nason, von Sachs and Kroisandt, 1998. This is used for smoothing of a wavelet periodogram and shouldn’t be used generally.

\texttt{manual} specify a user supplied threshold using \texttt{value} to pass the value of the threshold. The \texttt{value} argument should be a vector. If it is of length 1 then it is replicated to be the same length as the \texttt{levels} vector, otherwise it is repeated as many times as is necessary to be the \texttt{levels} vector’s length. In this way, different thresholds can be supplied for different levels. Note that the \texttt{by.level} option has no effect with this policy.


\texttt{universal} See Donoho and Johnstone, 1995.

Author(s)

G P Nason

See Also

\texttt{AvBasis}, \texttt{AvBasis.wst}, \texttt{InvBasis}, \texttt{InvBasis.wst}, \texttt{MaNoVe}, \texttt{MaNoVe.wst}, \texttt{wst}, \texttt{wst.object}, \texttt{threshold}. 
**Description**

Corresponds to the wavelet thresholding routine developed by Ogden and Parzen (1994) Data dependent wavelet thresholding in nonparametric regression with change-point applications. *Tech Rep 176*, University of South Carolina, Department of Statistics.

**Usage**

`TOgetthrda1(dat, alpha)`
`TOgetthrda2(dat, alpha)`
`TOkolsmi.chi2(dat)`
`TOonebyone1(dat, alpha)`
`TOonebyone2(dat, alpha)`
`TOshrinkit(coeffs, thresh)`

**Arguments**

- `dat` data
- `alpha` a p-value, generally smoothing parameter
- `coeffs` Some coefficients to be shrunk
- `thresh` a threshold

**Details**

Not intended for direct use.

**Value**

Various depending on the function

**Author(s)**

Todd Ogden

**See Also**

`TOthreshda1`, `TOthreshda2`, `threshold`
TOthreshda1

Data analytic wavelet thresholding routine

Description

This function might be better called using the regular threshold function using the op1 policy. Corresponds to the wavelet thresholding routine developed by Ogden and Parzen (1994) Data dependent wavelet thresholding in nonparametric regression with change-point applications. Tech Rep 176, University of South Carolina, Department of Statistics.

Usage

TOthreshda1(ywd, alpha = 0.05, verbose = FALSE, return.threshold = FALSE)

Arguments

ywd
The wd.object that you wish to threshold.

alpha
The smoothing parameter which is a p-value

verbose
Whether messages get printed

return.threshold
If TRUE then the threshold value gets returned rather than the actual thresholded object

Details

The TOthreshda1 method operates by testing the max of each set of squared wavelet coefficients to see if it behaves as the nth order statistic of a set of independent chi^2(1) r.v.’s. If not, it is removed, and the max of the remaining subset is tested, continuing in this fashion until the max of the subset is judged not to be significant.

In this situation, the level of the hypothesis tests, alpha, has default value 0.05. Note that the choice of alpha controls the smoothness of the resulting wavelet estimator – in general, a relatively large alpha makes it easier to include coefficients, resulting in a more wiggly estimate; a smaller alpha will make it more difficult to include coefficients, yielding smoother estimates.

Value

Returns the threshold value if return.threshold==TRUE otherwise returns the shrunk set of wavelet coefficients.

Author(s)

Todd Ogden

See Also

threshold, TOthreshda2, wd
**Description**

This function might be better called using the regular `threshold` function using the op2 policy. Corresponds to the wavelet thresholding routine developed by Ogden and Parzen (1994) Data dependent wavelet thresholding in nonparametric regression with change-point applications. *Tech Rep 176*, University of South Carolina, Department of Statistics.

**Usage**

```r
TOthreshda2(ywd, alpha = 0.05, verbose = FALSE, return.threshold = FALSE)
```

**Arguments**

- `ywd`: The `wd.object` that you wish to threshold.
- `alpha`: The smoothing parameter which is a p-value
- `verbose`: Whether messages get printed
- `return.threshold`: If TRUE then the threshold value gets returned rather than the actual thresholded object

**Details**

The `TOthreshda2` method operates in a similar fashion to `TOthreshda1` except that it takes the cumulative sum of squared coefficients, creating a sample "Brownian bridge" process, and then using the standard Kolmogorov-Smirnov statistic in testing.

In this situation, the level of the hypothesis tests, alpha, has default value 0.05. Note that the choice of alpha controls the smoothness of the resulting wavelet estimator – in general, a relatively large alpha makes it easier to include coefficients, resulting in a more wiggly estimate; a smaller alpha will make it more difficult to include coefficients, yielding smoother estimates.

**Value**

Returns the threshold value if `return.threshold`=TRUE otherwise returns the shrunk set of wavelet coefficients.

**Author(s)**

Todd Ogden

**See Also**

`threshold, TOthreshda1, wd`
Description

Performs the tensor product 2D wavelet transform. This is a related, but different, 2D wavelet transform compared to \texttt{imwd}.

Usage

\begin{verbatim}
tpwd(image, filter.number = 10, family = "DaubLeAsymm", verbose = FALSE)
\end{verbatim}

Arguments

- \texttt{image}: The image you wish to subject to the tensor product WT
- \texttt{filter.number}: The smoothness of wavelet, see \texttt{filter.select}
- \texttt{family}: The wavelet family you wish to use
- \texttt{verbose}: Whether or not you wish to print out informative messages

Details

The transform works by first taking the regular 1D wavelet transform across all columns in the image and storing these coefficients line by line back into the image. Then to this new image we apply the regular 1D wavelet transform across all rows in the image.

Hence, the top-left coefficient is the smoothed version both horizontally and vertically. The left-most row contains the image smoothed horizontally, but then detail picked up amongst the horizontal smooths vertically.

Suggested by Rainer von Sachs.

Value

A list with the following components:

- \texttt{tpwd}: A matrix with the same dimensions as the input \texttt{image}, but containing the tensor product wavelet transform coefficients.
- \texttt{filter.number}: The filter number used
- \texttt{family}: The wavelet family used
- \texttt{type}: The type of transform used
- \texttt{bc}: The boundary conditions used
- \texttt{date}: When the transform occurred

Author(s)

G P Nason
See Also

`imwd`, `tpwr`

Examples

```r
data(lennon)
ltpwd <- tpwd(lennon)
## Not run: image(log(abs(ltpwd$tpwd)), col=grey(seq(from=0, to=1, length=100)))
```

---

**tpwr**

*Inverse tensor product 2D wavelet transform.*

Description

Performs the inverse transform to `tpwd`.

Usage

```r
tpwr(tpwdobj, verbose = FALSE)
```

Arguments

- `tpwdobj` An object which is a list which contains the items indicated in the return value of `tpwd`
- `verbose` Whether informative messages are printed

Details

Performs the inverse transform to `tpwd`.

Value

A matrix, or image, containing the inverse tensor product wavelet transform of the image contained in the `tpwd` component of the `tpwdobj` object.

Author(s)

G P Nason

See Also

`imwr`, `tpwd`
Examples

```r
data(lennon)
ltpwd <- tpwd(lennon)
# # now perform the inverse and compare to the original
# ltpwr <- tpwr(ltpwd)
sum((ltpwr - lennon)^2)
# [1] 9.22802e-10
```

uncompress  Uncompress objects

Description

Uncompress objects.

This function is generic.

Particular methods exist. For the `imwdc.object` class object this generic function uses `uncompress.imwdc`.

There is a default uncompression method: `uncompress.default` that works on vectors.

Usage

`uncompress(...)`

Arguments

... See individual help pages for details.

Details

See individual method help pages for operation and examples

Value

A uncompressed version of the input.

RELEASE

Version 2.0 Copyright Guy Nason 1993

Author(s)

G P Nason

See Also

`uncompress.default, uncompress.imwdc, imwd, imwd.object, imwdc.object, threshold.imwd`
uncompress.default  Undo zero run-length encoding for a vector.

Description
This function inverts the action carried out by the `compress.default` function.

Usage
```r
## Default S3 method:
uncompress(v, verbose=FALSE, ...)
```

Arguments
- `v` The object to uncompress
- `verbose` Print an informative message whilst executing
- `...` Other arguments

Details
The inverse of `compress.default`

Value
The uncompressed, reinstated, vector.

Author(s)
G P Nason

See Also
`compress.default`, `uncompress`

Examples
```r
uncompress(compress(c(1, rep(0,99), 1)))
```

# [1] 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
# [38] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
# [75] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
Description

An `imwdc.object` is a run-length encoded object, essentially has all zeroes removed and only non-zero elements stored. This function undoes the compression.

Usage

```r
## S3 method for class 'imwdc'
uncompress(x, verbose=FALSE, ...)
```

Arguments

- `x` The object to uncompress
- `verbose` If TRUE then print out messages
- `...` Other arguments

Details

Description says all, inverse of `compress.imwd` function.

Value

The uncompressed `imwd.object`.

Author(s)

G P Nason

See Also

`imwd, compress.imwd`

Examples

```r
data(lennon)
# # Do 2D wavelet transform on lennon image
# lwd <- imwd(lennon)
# # Do threshold the wavelet coefficients, a lot of zeroes are present
# lmdT <- threshold(lwd)
# # What is the class of the thresholded object?
```
## Description

Use mouse to select which wavelets to enter a wavelet synthesis, continually plot the reconstruction and the wavelet tableaux.

## Usage

```r
wavegrow(n = 64, filter.number = 10, family = "DaubLeAsymm", type = "wavelet", random = TRUE, read.value = TRUE, restart = FALSE)
```

## Arguments

- **n**: Number of points in the decomposition
- **filter.number**: The wavelet filter.number to use, see `filter.select`
- **family**: The wavelet family to use in the reconstruction
- **type**: If "wavelet" then carry out the regular wavelet transform, otherwise if "station" do the nondecimated transform.
- **random**: If TRUE then iid Gaussian coefficients are inserted into the tableaux. If FALSE and `read.value`=TRUE then the user is promoted for a value, otherwise the value 1 is inserted into the tableaux at the selected point.
- **read.value**: If TRUE then a value is read and used to insert that size of wavelet coefficient at the selected point. If FALSE then a coefficient of size 1 is inserted.
If TRUE then after a coefficient has been inserted, and plots done, the next selection causes all the coefficients to be reset to zero and a single coefficient inserted. This actually has the overall action of being able to select a coefficient location and view the size and shape of the wavelet produced.

Details

This function can perform many slightly different actions. However, the basic idea is for a tableaux of wavelet coefficients to be displayed in one graphics window, and the reconstruction of those coefficients to be displayed in another graphics window.

Hence, two graphics windows, capable of plotting and mouse interaction (e.g. X11, windows or quartz) with the locator function, are required to be active.

When the function starts up an initial random tableaux is displayed and its reconstruction.

The next step is for the user to select coefficients on the tableaux. What happens next specifically depends on the arguments above. By default selecting a coefficient causes that coefficient scale and location to be identified, then a random sample is taken from a N(0,1) random variable and assigned to that coefficient. Hence, the tableaux is updated, the reconstruction with the new coefficient computed and both are plotted.

If type="wavelet" is used then decimated wavelets are used, if type="station" then the time-ordered non-decimated wavelets are used.

If random=FALSE then new values for the coefficients are either selected (by asking the user for input) if read.value=TRUE or the value of 1 is input.

If restart=TRUE then the function merely displays the wavelet associated with the selected coefficient. Hence, this option is useful to demonstrate to people how wavelets from different points of the tableaux have different sizes, scales and locations.

If the mouse locator function is exited (this can be a right-click in some windowing systems, or pressing ESCAPE) then the function asks whether the user wishes to continue. If not then the function returns the current tableux. Hence, this function can be useful for users to build their own tabeleaux.

Value

The final tableaux.

Author(s)

G P Nason

See Also

wd
WaveletCV

**Wavelet cross-validation**

**Description**

Two-fold wavelet shrinkage cross-validation (there is a faster C based version CWCV.)

**Usage**

WaveletCV(ynoise, x = 1:length(ynoise), filter.number = 10, family = "DaubLeAsymm", thresh.type = "soft", tol = 0.01, verbose = 0, plot.it = TRUE, ll=3)

**Arguments**

- `ynoise`: A vector of dyadic (power of two) length that contains the noisy data that you wish to apply wavelet shrinkage by cross-validation to.
- `x`: This function is capable of producing informative plots. It can be useful to supply the x values corresponding to the ynoise values. Further this argument is returned by this function which can be useful for later processors.
- `filter.number`: This selects the smoothness of wavelet that you want to perform wavelet shrinkage by cross-validation.
- `family`: specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
- `thresh.type`: this option specifies the thresholding type which can be "hard" or "soft".
- `tol`: this specifies the convergence tolerance for the cross-validation optimization routine (a golden section search).
- `verbose`: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
- `plot.it`: If this is TRUE then plots of the universal threshold (used to obtain an upper bound on the cross-validation threshold) reconstruction and the resulting cross-validation estimate are produced.
- `ll`: The primary resolution that you wish to assume. No wavelet coefficients that are on coarser scales than ll will be thresholded.

**Details**

**Note**: a faster C based implementation of this function called CWCV is available. It takes the same arguments (although it has one extra minor argument) and returns the same values.

Compute the two-fold cross-validated wavelet shrunk estimate given the noisy data ynoise according to the description given in Nason, 1996.

You must specify a primary resolution given by ll. This must be specified individually on each data set and can itself be estimated using cross-validation (although I haven’t written the code to do this).

Note. The two-fold cross-validation method performs very badly if the input data is correlated. In this case I would advise using other methods.
Value

A list with the following components

- **x**: This is just the x that was input. It gets passed through more or less for convenience for the user.
- **ynoise**: A copy of the input ynoise noisy data.
- **xvwr**: The cross-validated wavelet shrunk estimate.
- **yuvtwr**: The universal thresholded version (note this is merely a starting point for the cross-validation algorithm. It should not be taken seriously as an estimate. In particular its estimate of variance is likely to be inflated.)
- **xvthresh**: The cross-validated threshold
- **uvthresh**: The universal threshold (again, don't take this value too seriously. You might get better performance using the threshold function directly with specialist options.
- **xvdof**: The number of non-zero coefficients in the cross-validated shrunk wavelet object (which is not returned).
- **uvdof**: The number of non-zero coefficients in the universal threshold shrunk wavelet object (which also is not returned)
- **xkeep** always returns NULL!
- **fkeep** always returns NULL!

Author(s)

G P Nason

See Also

*CWCV,Crswav,rsswav,threshold.wd*

Examples

```
# This function is best used via the policy="cv" option in
# the threshold.wd function.
# See examples there.
#
```

**wd**

*Wavelet transform (decomposition).*

Description

This function can perform two types of discrete wavelet transform (DWT). The standard DWT computes the DWT according to Mallat’s pyramidal algorithm (Mallat, 1989) (it also has the ability to compute the *wavelets on the interval* transform of Cohen, Daubechies and Vial, 1993).

The non-decimated DWT (NDWT) contains all possible shifted versions of the DWT. The order of computation of the DWT is O(n), and it is O(n log n) for the NDWT if n is the number of data points.
Usage

wd(data, filter.number=10, family="DaubLeAsymm", type="wavelet",
    bc="periodic", verbose=FALSE, min.scale=0, precond=TRUE)

Arguments

data A vector containing the data you wish to decompose. The length of this vector
must be a power of 2.

filter.number This selects the smoothness of wavelet that you want to use in the decompo-
sition. By default this is 10, the Daubechies least-asymmetric orthonormal comp-
actly supported wavelet with 10 vanishing moments.

For the “wavelets on the interval” (bc="interval") transform the filter number
ranges from 1 to 8. See the table of filter coefficients indexed after the reference

family specifies the family of wavelets that you want to use. Two popular options are
"DaubExPhase" and "DaubLeAsymm" but see the help for filter.select for
more possibilities.

This argument is ignored for the “wavelets on the interval” transform (bc="interval").
Note that, as of version 4.6.1 you can use the Lina-Mayrand complex-valued
wavelets.

type specifies the type of wavelet transform. This can be "wavelet" (default) in which
case the standard DWT is performed (as in previous releases of WaveThresh).
If type is "station" then the non-decimated DWT is performed. At present, only
periodic boundary conditions can be used with the non-decimated wavelet trans-
form.

bc specifies the boundary handling. If bc="periodic" the default, then the func-
yion you decompose is assumed to be periodic on it's interval of definition, if
bc="symmetric" then the function beyond its boundaries is assumed to be a
symmetric reflection of the function in the boundary. The symmetric option
was the implicit default in releases prior to 2.2. If bc="interval" then the
“wavelets on the interval algorithm” due to Cohen, Daubechies and Vial is
used. (The WaveThresh implementation of the “wavelets on the interval trans-
form” was coded by Piotr Fryzlewicz, Department of Mathematics, Wroclaw
University of Technology, Poland; this code was largely based on code written
by Markus Monnerjahn, RHRK, Universitat Kaiserslautern; integration into
WaveThresh by GPN. See the nice project report by Piotr on this piece of code).

verbose Controls the printing of "informative" messages whilst the computations progress.
Such messages are generally annoying so it is turned off by default.

min.scale Only used for the “wavelets on the interval transform”. The wavelet algorithm
starts with fine scale data and iteratively coarsens it. This argument controls how
many times this iterative procedure is applied by specifying at which scale level
to stop decomposing.

precond Only used for the “wavelets on the interval transform”. This argument specifies
whether preconditioning is applied (called prefiltering in Cohen, Daubechies
and Vial, 1993.) Preconditioning ensures that sequences like 1,1,1,1 or 1,2,3,4
map to zero high pass coefficients.
Details

If type=="wavelet" then the code implements Mallat’s pyramid algorithm (Mallat 1989). For more
details of this implementation see Nason and Silverman, 1994. Essentially it works like this: you
start off with some data cm, which is a real vector of length $2^m$, say.

Then from this you obtain two vectors of length $2^{(m-1)}$. One of these is a set of smoothed data,
c(m-1), say. This looks like a smoothed version of cm. The other is a vector, d(m-1), say. This
corresponds to the detail removed in smoothing cm to c(m-1). More precisely, they are the coeffi-
cients of the wavelet expansion corresponding to the highest resolution wavelets in the expansion.
Similarly, c(m-2) and d(m-2) are obtained from c(m-1), etc. until you reach c0 and d0.

All levels of smoothed data are stacked into a single vector for memory efficiency and ease of
transport across the SPlus-C interface.

The smoothing is performed directly by convolution with the wavelet filter (filter.select(n)$H,
especially low-pass filtering), and then dyadic decimation (selecting every other datum, see Vaidyanathan
(1990)). The detail extraction is performed by the mirror filter of H, which we call G and is a band-
pass filter. G and H are also known quadrature mirror filters.

There are now two methods of handling "boundary problems". If you know that your function
is periodic (on it’s interval) then use the bc="periodic" option, if you think that the function is
symmetric reflection about each boundary then use bc="symmetric". You might also consider using
the "wavelets on the interval" transform which is suitable for data arising from a function that is
known to be defined on some compact interval, see Cohen, Daubechies, and Vial, 1993. If you
don’t know then it is wise to experiment with both methods, in any case, if you don’t have very
much data don’t infer too much about your decomposition! If you have loads of data then don’t
infer too much about the boundaries. It can be easier to interpret the wavelet coefficients from a
bc="periodic" decomposition, so that is now the default. Numerical Recipes implements some of
the wavelets code, in particular we have compared our code to "wtl" and "daub4" on page 595. We
are pleased to announce that our code gives the same answers! The only difference that you might
notice is that one of the coefficients, at the beginning or end of the decomposition, always appears
in the "wrong" place. This is not so, when you assume periodic boundaries you can imagine the
function defined on a circle and you can basically place the coefficient at the beginning or the end
(because there is no beginning or end, as it were).

The non-deciated DWT contains all circular shifts of the standard DWT. Naively imagine that you
do the standard DWT on some data using the Haar wavelets. Coefficients 1 and 2 are added and
difference, and also coefficients 3 and 4; 5 and 6 etc. If there is a discontinuity between 1 and 2 then
you will pick it up within the transform. If it is between 2 and 3 you will loose it. So it would be
nice to do the standard DWT using 2 and 3; 4 and 5 etc. In other words, pick up the data and rotate
it by one position and you get another transform. You can do this in one transform that also does
more shifts at lower resolution levels. There are a number of points to note about this transform.

Note that a time-ordered non-deciated wavelet transform object may be converted into a packet-ordered
non-deciated wavelet transform object (and vice versa) by using the convert function.

The NDWT is translation equivariant. The DWT is neither translation invariant or equivariant. The
standard DWT is orthogonal, the non-deciated transform is most definitely not. This has the added
disadvantage that non-deciated wavelet coefficients, even if you supply independent normal noise.
This is unlike the standard DWT where the coefficients are independent (normal noise).

You might like to consider growing wavelet syntheses using the wavegrow function.
Value

An object of class \texttt{wd}.

For boundary conditions apart from \texttt{bc=\textquoteleft interval\textquoteleft} this object is a list with the following components.

\begin{itemize}
  \item \texttt{C} Vector of sets of successively smoothed data. The pyramid structure of Mallat is stacked so that it fits into a vector. The function \texttt{accessC} should be used to extract a set for a particular level.
  \item \texttt{D} Vector of sets of wavelet coefficients at different resolution levels. Again, Mallat's pyramid structure is stacked into a vector. The function \texttt{accessD} should be used to extract the coefficients for a particular resolution level.
  \item \texttt{nlevelsWT} The number of resolution levels. This depends on the length of the data vector. If \texttt{length(data)=2^m}, then there will be \texttt{m} resolution levels. This means there will be \texttt{m} levels of wavelet coefficients (indexed \texttt{0,1,2,...,(m-1)}), and \texttt{m+1} levels of smoothed data (indexed \texttt{0,1,2,...,m}).
  \item \texttt{fl.dbase} There is more information stored in the \texttt{C} and \texttt{D} than is described above. In the decomposition "extra" coefficients are generated that help take care of the boundary effects, this database lists where these start and finish, so the "true" data can be extracted.
  \item \texttt{filter} A list containing information about the filter type: Contains the string "wavelet" or "station" depending on which type of transform was performed.
  \item \texttt{date} The date the transform was performed.
  \item \texttt{bc} How the boundaries were handled.
\end{itemize}

If the "wavelets on the interval" transform is used (i.e. \texttt{bc=\textquoteleft interval\textquoteleft}) then the internal structure of the \texttt{wd} object is changed as follows.

\begin{itemize}
  \item The coefficient vectors \texttt{C} and \texttt{D} have been replaced by a single vector \texttt{transformed.vector}. The new single vector contains just the transformed coefficients: i.e. the wavelet coefficients down to a particular scale (determined by \texttt{min.scale} above). The scaling function coefficients are stored first in the array (there will be \texttt{2^min.scale} of them). Then the wavelet coefficients are stored as consecutive vectors coarsest to finest of length \texttt{2^min.scale}, \texttt{2^(min.scale+1)} up to a vector which is half of the length of the original data.)
  \item In any case the user is recommended to use the functions \texttt{accessC}, \texttt{accessD}, \texttt{putC} and \texttt{putD} to access coefficients from the \texttt{wd} object.
  \item The extra component \texttt{current.scale} records to which level the transform has been done (usually this is \texttt{min.scale} as specified in the arguments).
  \item The extra component \texttt{filters.used} is a vector of integers that record which filter index was used as each level of the decomposition. At coarser scales sometimes a wavelet with shorter support is needed.
  \item The extra logical component \texttt{preconditioned} specifies whether preconditioning was turned on or off.
  \item The component \texttt{fl.dbase} is still present but only contains data corresponding to the storage of the coefficients that are present in \texttt{transformed.vector}. In particular, since only one scale of the father wavelet coefficients is stored the component \texttt{first.last.c} of \texttt{fl.dbase} is now a
\end{itemize}
three-vector containing the indices of the first and last entries of the father wavelet coefficients and the offset of where they are stored in transformed.vector. Likewise, the component first.last.d of fl.dbase is still a matrix but there are now only rows for each scale level in the transformed.vector (something like nlevelsWT(wd) - wd$current.scale).

- The filter coefficient is also slightly different as the filter coefficients are no longer stored here (since they are hard coded into the wavelets on the interval transform.)

RELEASE

Version 3.5.3 Copyright Guy Nason 1994 Integration of “wavelets on the interval” code by Piotr Fryzlewicz and Markus Monnerjahn was at Version 3.9.6, 1999.

Author(s)

G P Nason

See Also

wd.int, wr, wr.int, wr.wd, accessC, accessD, putD, putC, filter.select, plot.wd, threshold, wavegrow

Examples

```r
# Generate some test data
#
test.data <- example.1()$y
## Not run: ts.plot(test.data)
#
# Decompose test.data and plot the wavelet coefficients
#
wds <- wd(test.data)
## Not run: plot(wds)
#
# Now do the time-ordered non-decimated wavelet transform of the same thing
#
wdS <- wd(test.data, type="station")
## Not run: plot(wdS)
#
# Next examples
#************
# The chirp signal is also another good examples to use.
#
# Generate some test data
#
test.chirp <- simchirp()$y
## Not run: ts.plot(test.chirp, main="Simulated chirp signal")
#
# Now let’s do the time-ordered non-decimated wavelet transform.
# For a change let’s use Daubechies least-asymmetric phase wavelet with 8
# vanishing moments (a totally arbitrary choice, please don’t read
```
chirpwdS <- wd(test.chirp, filter.number=8, family="DaubLeAsymm", type="station")
## Not run: plot(chirpwdS, main="TOND WT of Chirp signal")

Note that the coefficients in this plot are exactly the same as those
generated by the packet-ordered non-decimated wavelet transform
except that they are in a different order on each resolution level.
See Nason, Sapatinas and Sawczenko, 1998
for further information.

wd.dh

**Compute specialized wavelet transform for density estimation**

**Description**

Computes the discrete wavelet transform, but with zero boundary conditions especially for density estimation.

**Usage**

```r
wd.dh(data, filter.number = 10, family = "DaubLeAsymm", type = "wavelet",
      bc = "periodic", firstk = NULL, verbose = FALSE)
```

**Arguments**

- `data`: The father wavelet coefficients
- `filter.number`: The smoothness of the underlying wavelet to use, see `filter.select`
- `family`: The wavelet family to use, see `filter.select`
- `type`: The type of wavelet to use
- `bc`: Type of boundary conditions
- `firstk`: A parameter that originates from `denproj`
- `verbose`: If TRUE then informative messages are printed.

**Details**

This is a subsidiary routine, not intended for direct user use for density estimation. The main routines for wavelet density estimation are `denwd`, `denproj`, `denwr`.

The input to this function should be projected father wavelet coefficients as computed by `denproj`, but usually supplied to this function by `denwd`.

Thresholding should be carried out by the user independently of these functions.

**Value**

An object of class `wd`, but assumed on the basis of zero boundary conditions.
**wd.int**

**Author(s)**

David Herrick

**See Also**

denproj, denwd

---

### Description

This function actually computes the "wavelets on the interval" transform.

**NOTE:** It is not recommended that the casual user call this function. The "wavelets on the interval" transform is best called in WaveThresh via the `wd` function with the argument `bc` argument set to "interval".

### Usage

```r
wd.int(data, preferred.filter.number, min.scale, precond)
```

### Arguments

- `data` : The data that you wish to apply the "wavelets on the interval" transform to.
- `preferred.filter.number` : Which wavelet to use to do the transform. This is an integer ranging from 1 to 8. See the Cohen, Daubeches and Vial (1993) paper. Wavelets that do not "overlap" a boundary are just like the ordinary Daubechies’ wavelets.
- `min.scale` : At which resolution level to transform to.
- `precond` : If true performs preconditioning of the input vector to try and ensure that simple polynomial sequences (less than in order to the wavelet used) map to zero elements.

### Details

(The WaveThresh implementation of the “wavelets on the interval transform” was coded by Piotr Fryzlewicz, Department of Mathematics, Wroclaw University of Technology, Poland; this code was largely based on code written by Markus Monnerjahn, RHRK, Universitat Kaiserslautern; integration into WaveThresh by GPN).

See the help on the "wavelets on the interval code" in the `wd` help page.

### Value

A list containing the wavelet transform of the data. We again emphasize that this list is not intended for human consumption, use the `wd` function with the correct `bc="interval"` argument.
RELEASE

Version 3.9.6 (Although Copyright Piotr Fryzlewicz and Markus Monnerjahn 1995-9).

Author(s)

Piotr Fryzlewicz

See Also

wd, wr, wr.int.

Examples

#  
# The user is expected to call the wr  
# for inverting a "wavelets on the interval transform" and not to use  
# this function explicitly  
#

wd.object

Wavelet decomposition objects

Description

These are objects of classes

wd

They represent a decomposition of a function with respect to a wavelet basis (or tight frame in the case of the (time-ordered) non-decimated wavelet decomposition).

Details

To retain your sanity the C and D coefficients should be extracted by the accessC and accessD functions and inserted using the putC and putD functions (or more likely, their methods), rather than by the $ operator.

Mind you, if you want to muck about with coefficients directly, then you’ll have to do it yourself by working out what the fl.dbase list means (see first.last for a description.)

Note the time-ordered non-decimated wavelet transform used to be called the stationary wavelet transform. In fact, the non-decimated transform has several possible names and has been reinvented many times. There are two versions of the non-decimated transform: the coefficients are the same in each version just ordered differently within a resolution level. The two transforms are

- The function wd() with an argument type="station" computes the time-ordered non-decimated transform (see Nason and Silverman, 1995) which is useful in time-series applications (see e.g. Nason, von Sachs and Kroisandt, 1998).
- The function wst() computes the packets ordered non-decimated transform is useful for curve estimation type applications (see e.g. Coifman and Donoho, 1995).
Value

The following components must be included in a legitimate ‘wd’ object.

C a vector containing each level’s smoothed data. The wavelet transform works by applying both a smoothing filter and a bandpass filter to the previous level’s smoothed data. The top level contains data at the highest resolution level. Each of these levels are stored one after the other in this vector. The matrix fl.dbase$first.last.c determines exactly where each level is stored in the vector. Likewise, coefficients stored when the NDWT has been used should only be extracted using the “access” and “put” functions below.

D wavelet coefficients. If you were to write down the discrete wavelet transform of a function then these D would be the coefficients of the wavelet basis functions. Like the C, they are also formed in a pyramidal manner, but stored in a linear array. The storage details are to be found in fl.dbase$first.last.d Likewise, coefficients stored when the NDWT has been used should only be extracted using the “access” and “put” functions below.

nlevelsWT The number of levels in the pyramidal decomposition that produces the coefficients. If you raise 2 to the power of nlevels you get the number of data points used in the decomposition.

fl.dbase The first last database associated with this decomposition. This is a list consisting of 2 integers, and 2 matrices. The matrices detail how the coefficients are stored in the C and D components of the ‘wd.object’. See the help on first.last for more information.

filter a list containing the details of the filter that did the decomposition

type either wavelet indicating that the ordinary wavelet transform was performed or station indicating that the time-ordered non-decimated wavelet transform was done.

date The date that the transform was performed or the wd was modified.

bc how the boundaries were handled

GENERATION

This class of objects is returned from the wd function to represent a (possibly time-ordered non-decimated) wavelet decomposition of a function. Many other functions return an object of class wd.

METHODS

The wd class of objects has methods for the following generic functions: plot, threshold, summary, print, codedraw.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994
wd3D

Three-dimensional discrete wavelet transform

Description

This function performs the 3D version of Mallat’s discrete wavelet transform (see Mallat, 1989, although this paper does not describe in detail the 3D version the extension is trivial). The function assumes periodic boundary conditions.

Usage

wd3D(a, filter.number=10, family="DaubLeAsymm")

Arguments

a
A three-dimensional array constructed using the S-Plus array() function. Each dimension of the array should be equal to the same power of two.

filter.number
This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family
specifies the family of wavelets that you want to use. Two popular options are "DaubExPhase" and "DaubLeAsymm" but see the help for filter.select for more possibilities.

Details

This function implements a straightforward extension of Mallat’s, (1989) one- and two-dimensional DWT. The algorithm recursively applies all possible combinations of the G and H detail and smoothing filters to each of the dimensions thus forming 8 different sub-blocks which we label HHH, GHH, HGH, GGH, HHG, GHG, HGG, and GGG. The algorithm recurses on the HHH component of each level (these are the father wavelet coefficients).

Making an analogy to the 2D transform where HH, HG, HG and GG is produced at each resolution level: the HG and GH correspond to "horizontal" and "vertical" detail and GG corresponds to "diagonal detail". The GGG corresponds to the 3D "diagonal" version, HGG corresponds to smoothing in dimension 1 and "diagonal" detail in dimensions 2 and 3, and so on. I don’t think there are words in the English language which adequately describe "diagonal" in 3D — maybe cross detail?

Value

An object of class wd3D.
wd3D.object

RELEASE

Version 3.9.6 Copyright Guy Nason 1997

Author(s)

G P Nason

See Also

wd, imwd, accessD.wd3D, print.wd3D, putD.wd3D, putDwd3Dcheck, summary.wd3D, threshold.wd3D, wd3D.object, wr3D.

Examples

```
# Generate some test data: 512 standard normal observations in an 8x8x8 array.
#
test.data.3D <- array(rnorm(8*8*8), dim=c(8,8,8))
#
# Now do the 3D wavelet transform
#
tdwd3D <- wd3D(test.data.3D)
#
# See examples explaining the 3D wavelet transform.
#
```

---

wd3D.object  

*Three-dimensional wavelet object*

Description

These are objects of classes wd3D

They contain the 3D discrete wavelet transform of a 3D array (with each dimension being the same dyadic size).

Details

To retain your sanity the wavelet coefficients at any resolution level in directions, GGG, GGH, GHG, GHH, HGG, HGH, HHG should be extracted by the `accessD()` function and inserted using the `putD` function rather than by the `$` operator.
The following components must be included in a legitimate ‘wd’ object.

- **a**: a three-dimensional array containing the 3D discrete wavelet coefficients. The coefficients are stored in a pyramid structure for efficiency.
- **nlevelsWT**: The number of levels in the pyramidal decomposition that produces the coefficients. If you raise 2 to the power of nlevels you get the number of data points used in each dimension of the decomposition.
- **filter.number**: the number of the wavelet family that did the DWT.
- **family**: the family of wavelets that did the DWT.
- **date**: the date that the transform was computed.

**generation**

This class of objects is returned from the wd3D function to represent a three-dimensional DWT of a 3D array. Other functions return an object of class wd3D.

**methods**

The wd3D class of objects has methods for the following generic functions: `accessD`, `print`, `putD`, `summary`, `threshold`.

**release**

Version 3.9.6 Copyright Guy Nason 1997

**Author(s)**

G P Nason

**See Also**

`wd3D, accessD, print, putD, summary, threshold, wr3D`.

---

**Whistory**

Obsolete function supposedly detailed history of object

**Description**

The original idea behind this obsolete function was to interrogate an object and return the modifications that had been successively applied to the function. The reason for this was that after a long data analysis session one would end up with a whole set of, e.g., thresholded or otherwise modified objects and it would have been convenient for each object not only to store its current value but also the history of how it got to be that value.
Usage

\texttt{Whistory(...)}

Arguments

\begin{itemize}
  \item \ldots \hspace{1cm} \text{Arguments to pass to method}
\end{itemize}

Details

Description says all

Value

No return value, although function was meant to print out a list times and dates when the object was modified.

Author(s)

G P Nason

See Also

\begin{itemize}
  \item \texttt{Whistory.wst}
\end{itemize}

\begin{tabular}{ll}
\texttt{Whistory.wst} & \textit{Obsolete function: as Whistory, but for wst objects} \\
\end{tabular}

Description

Obsolete function, see \texttt{Whistory}.

Usage

\begin{verbatim}
## S3 method for class 'wst'
Whistory(wst, all=FALSE, ...)
\end{verbatim}

Arguments

\begin{itemize}
  \item \texttt{wst} \hspace{1cm} \text{The object that you want to display the history for}
  \item \texttt{all} \hspace{1cm} \text{Print the whole history list}
  \item \ldots \hspace{1cm} \text{Other arguments}
\end{itemize}

Details

Description says all
Value

Nothing, but history information is printed.

Author(s)

G P Nason

See Also

`Whistory`

**wp**

*Wavelet packet transform.*

Description

This function computes a wavelet packet transform (computed by the complete binary application of the DH and DG packet operators, as opposed to the Mallat discrete wavelet transform which only recurses on the DH operator [low pass]).

Usage

```
wp(data, filter.number=10, family="DaubLeAsymm", verbose=FALSE)
```

Arguments

data A vector containing the data you wish to decompose. The length of this vector must be a power of 2.

filter.number This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

verbose if TRUE then (un)helpful messages are printed during the execution.

Details


Value

An object of class **wp** which contains the (decimated) wavelet packet coefficients.

RELEASE

Version 3.0 Copyright Guy Nason 1994
**wp.object**

**Author(s)**

G P Nason

**See Also**

accessC.wp, accessD.wp, basisplot.wp, draw.wp, drawwp.default, filter.select, getpacket.wp, InvBasis.wp, MaNoVe.wp, plot.wp, print.wp, putC.wp, putD.wp, putpacket.wp, summary.wp, threshold.wp, wp.object.

**Examples**

```r
v <- rnorm(128)
wvp <- wp(v)
```

---

**wp.object**

*Wavelet Packet decomposition objects.*

**Description**

These are objects of classes `wp` They represent a decomposition of a function with respect to a set of wavelet packet functions.

**Details**

To retain your sanity we recommend that wavelet packets be extracted in one of two ways:

- use `getpacket.wp` to obtain individual packets.
- use `accessD.wp` to obtain all coefficients at a particular resolution level.

You can obtain the coefficients directly from the `wp$wp` component but you have to understand their organization described above.

**Value**

The following components must be included in a legitimate ‘wp’ object.

`wp` a matrix containing the wavelet packet coefficients. Each row of the matrix contains coefficients with respect to a particular resolution level. There are `nlevelsWT(wp)+1` rows in the matrix. Row `nlevels(wp)+1` (the “bottom”) row contains the “original” data used to produce the wavelet packet coefficients. Rows `nlevels(wp)` to row 1 contain coefficients at resolution levels `nlevels(wp)-1` to 0 (so the first row contains coefficients at resolution level 0). The columns contain the coefficients with respect to packets. A different packet length exists at each resolution level. The packet length at resolution level `i` is given by `2^i`. However, the `getpacket.wp` function should be used to access individual packets from a `wp` object.
wpst

nlevelsWT  The number of levels in the wavelet packet decomposition. If you raise 2 to the power of nlevels you get the number of data points used in the decomposition.

filter a list containing the details of the filter that did the decomposition (equivalent to the return value from the filter.select function).

date The date that the transform was performed or the wp was modified.

GENERATION

This class of objects is returned from the wp function to represent a wavelet packet decomposition of a function. Many other functions return an object of class wp.

METHODS

The wp class of objects has methods for the following generic functions: InvBasis, MaNoVe, accessC, accessD, basisplot, draw, getpacket, nlevelsWT, plot, print, putC, putD, putpacket, summary, threshold.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

wp

Description

This function computes the non-decimated wavelet packet transform as described by Nason, Sapatinas and Sawczenko, 1998. The non-decimated wavelet packet transform (NWPT) contains all possible shifted versions of the wavelet packet transform.

Usage

wpst(data, filter.number=10, family="DaubLeAsymm", FinishLevel)
Arguments

data A vector containing the data you wish to decompose. The length of this vector must be a power of 2.

filter.number This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

FinishLevel At which level to stop decomposing. The full decomposition decomposes to level 0, but you could stop earlier.

Details

This function computes the packet-ordered non-decimated wavelet packet transform of data as described by Nason, Sapatinas and Sawczenko, 1998. It assumes periodic boundary conditions. The order of computation of the NWPT is $O(n^2)$ if $n$ is the number of input data points.

Packets can be extracted from the wpst.object produced by this function using the getpacket.wpst function. Whole resolution levels of non-decimated wavelet packet coefficients in time order can be obtained by using the accessD.wpst function.

Value

An object of class wpst containing the discrete packet-ordered non-decimated wavelet packet coefficients.

RELEASE

Version 3.8.8 Copyright Guy Nason 1997

Author(s)

G P Nason

See Also

accessD, accessD.wpst, filter.select, getpacket, getpacket.wpst, makewpstDO

Examples

v <- rnorm(128)
wpst <- wpst(v)
wpst2discr  
Reshape/reformat packet coefficients into a multivariate data set

Description
The packet coefficients of a nondecimated wavelet packet object are stored internally in an efficient form. This function takes the nondecimated wavelet packets and stores them as a matrix (multivariate data set). Each column in the returned matrix corresponds to an individual packet, each row corresponds to a time index in the original packet or time series.

Usage
wpst2discr(wpstobj, groups)

Arguments
wpstobj  A wpst class object, output from wpst say
groups   A time series containing the group membership at each time point

Details
Description says it all

Value
An object of class w2d which is a list containing the following items:

m       The matrix containing columns of packet information.
groups  Passes through the group argument from input.
level   Each column corresponds to a packet, this vector contains the information on which resolution level each packet comes from
pktix   Like for level but for packet indices
nlevelsWT The number of resolution levels in total, from the wpst object

Author(s)
G P Nason

See Also
makewpstDO, wpst
wpst2m

Converts a nondecimated wavelet packet object to a (large) matrix with packets stored as columns

Description

Takes a nondecimated wavelet packet transform, takes the packets one packet at a time and stores them in a matrix. The packets are rotated on extraction and storage in the matrix in an attempt to align them, they are also optionally transformed by `trans`. The rotation is performed by `compgrot`. Note that the coefficients are of some series, not the basis functions themselves.

Usage

```r
wpst2m(wpstobj, trans = identity)
```

Arguments

- `wpstobj`: The nondecimated wavelet packet object to store
- `trans`: The optional transform to apply to the coefficients

Details

Description says all

Value

A list, of class `w2m`, with the following components:

- `m`: The matrix containing the packets
- `level`: A vector containing the levels from where the packets in `m` come from
- `pktix`: A vector containing the packet indices from where the packets in `m` come from
- `nlevelsWT`: The number of resolution levels from the original wpst object

Author(s)

G P Nason

See Also

- `makewpstRO`, `print.w2m`

Examples

```r
#
# Not intended to be directly used by users
#```
wpstCLASS

Predict values using new time series values via a non-decimated wavelet packet discrimination object.

Description

Given a timeseries (`timeseries`) and another time series of categorical values (`groups`) the `makewpstdo` produces a model that permits discrimination of the `groups` series using a discriminant analysis based on a restricted set of non-decimated wavelet packet coefficients of `timeseries`. The current function enables new timeseries data, to be used in conjunction with the model to generate new, predicted, values of the `groups` time series.

Usage

```r
wpstCLASS(newTS, wpstDO)
```

Arguments

- `newTS`: A new segment of time series values, of the same time series that was used as the dependent variable used to construct the `wpstDO` object
- `wpstDO`: An object that uses values of a dependent time series to build a discriminatory model of a `groups` time series. Output from the `makewpstdo` function

Details

This function performs the same nondecimated wavelet packet (NDWPT) transform of the `newTS` data that was used to analyse the original `timeseries` and the details of this transform are stored within the `wpstDO` object. Then, using information that was recorded in `wpstDO` the packets with the same level/index are extracted from the new NDWPT and formed into a matrix. Then the linear discriminant variables, again stored in `wpstDO` are used to form predictors of the original `groups` time series, ie new values of `groups` that correspond to the new values of `timeseries`.

Value

The prediction using the usual R `predict.lda` function. The predicted values are stored in the `class` component of that list.

Author(s)

G P Nason

See Also

- `makewpstdo`
Examples

#
# See example at the end of help page for makewpstDO
#

**wpstREGR**

*Construct data frame using new time series using information from a previously constructed wpstRO object*

Description

The **makewpstRO** function takes two time series, performs a nondecimated wavelet packet transform with the "dependent" variable one, stores the "best" packets (those that individually correlate with the response series) and returns the data frame that contains the response and the best packets. The idea is that the user then performs some kind of modelling between response and packets. This function takes a new "dependent" series and returns the best packets in a new data frame in the same format as the old one. The idea is that the model and the new data frame can be used together to predict new values for the response.

Usage

```
wpstREGR(newTS, wpstRO)
```

Arguments

- **newTS**: The new "dependent" time series
- **wpstRO**: The previously constructed wpstRO object made by **makewpstRO**

Details

Description says it all.

Value

New values of the response time series.

Author(s)

G P Nason

References

See reference to Nason and Sapatinas paper in the help for **makewpstRO**.

See Also

**makewpstRO**, **wpst**
Examples

# See extended example in makewpsR0 help, includes example of using this fn
#

\texttt{wr} \hspace{2cm} \textit{Wavelet reconstruction (inverse DWT)}. \\

Description

Performs inverse discrete wavelet transform.

This function is generic.

Particular methods exist. For the \texttt{wd} class object this generic function uses \texttt{wr.wd}.

Usage

\texttt{wr(...)}

Arguments

\ldots \text{ See individual help pages for details.}

Details

See individual method help pages for operation and examples.

Value

Usually the wavelet reconstruction of \texttt{x}. Although the return value varies with the precise method used.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

\texttt{wd, wd.object, wr.wd}
Description
This function actually computes the inverse of the "wavelets on the interval" transform.

Usage

## S3 method for class 'int'
wr(wav.int.object, ...)

Arguments

wav.int.object A list with components defined by the return from the wd.int function.

... any other arguments

Details

(The WaveThresh implementation of the “wavelets on the interval transform” was coded by Piotr Fryzlewicz, Department of Mathematics, Wroclaw University of Technology, Poland; this code was largely based on code written by Markus Monnerjahn, RHRK, Universitat Kaiserslautern; integration into WaveThresh by GPN).

See the help on the "wavelets on the interval code" in the wd help page.

Value
The inverse wavelet transform of the wav.int.object supplied.

RELEASE
Version 3.9.6 (Although Copyright Piotr Fryzlewicz and Markus Monnerjahn 1995-9).

Note
It is not recommended that the casual user call this function. The "wavelets on the interval" transform is best called in WaveThresh via the wd function with the argument bc argument set to "interval".

Author(s)
Piotr Fryzlewicz and Markus Monnerjahn

See Also
wd.int, wd, wr.
Examples

```r
# The user is expected to call the wr
# for inverting a "wavelets on the interval transform".
#
```

Description

This function is method for the `function` to apply the inverse multiple wavelet transform for `mwd.object` objects.

Usage

```r
## S3 method for class 'mwd'
wr(...)
```

Arguments

```r
... Arguments to the mwr function.
```

Details

The function is merely a wrapper for `mwr`.

Value

The same return value as for `mwr`.

Author(s)

Tim Downie

See Also

`mwd`, `mwr`
Wavelet reconstruction for wd class objects (inverse discrete wavelet transform).

Description

This function performs the reconstruction stage of Mallat’s pyramid algorithm (Mallat 1989), i.e. the discrete inverse wavelet transform. The actual transform is performed by some C code, this is dynamically linked into S (if your machine can do this).

Usage

```r
## S3 method for class 'wd'
wr(wd, start.level = 0, verbose = FALSE, bc = wd$bc,
  return.object = FALSE, filter.number = wd$filter$filter.number,
  family = wd$filter$family, ...)
```

Arguments

- **wd**: A wavelet decomposition object as returned by `wd`, and described in the help for that function and the help for `wd.object`.
- **start.level**: The level you wish to start reconstruction at. The is usually the first (level 0). This argument is ignored for a wd object computed using the “wavelets on the interval” transform (i.e. using the bc=”interval” option of `wd`.
- **verbose**: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.
- **bc**: The boundary conditions used. Usually these are determined by those used to create the supplied wd object, but you sometimes change them with possibly silly results.
- **filter.number**: The filter number of the wavelet used to do the reconstruction. Again, as for bc, you should probably leave this argument alone. Ignored if the bvc component of the wd object is "interval".
- **family**: The type of wavelet used to do the reconstruction. You can change this argument from the default but it is probably NOT wise. Ignored if the bvc component of the wd object is "interval".
- **return.object**: If this is F then the top level of the reconstruction is returned (this is the reconstructed function at the highest resolution). Otherwise if it is T the whole wd reconstructed object is returned. Ignored if the bvc component of the wd object is "interval".
- **...**: any other arguments
Details

The code implements Mallat’s inverse pyramid algorithm. In the reconstruction the quadrature mirror filters G and H are supplied with c0 and d0, d1, ... d(m- 1) (the wavelet coefficients) and rebuild c1,..., cm.

If the bc component of the wd object is “interval” then the wr.int function which implements the inverse “wavelet on the interval” transform due to Cohen, Daubechies and Vial, 1993 is used instead.

Value

Either a vector containing the top level reconstruction or an object of class wd containing the results of the reconstruction, details to be found in help for wd.object.

RELEASE

Version 3 Copyright Guy Nason 1994 Integration of “wavelets on the interval” code by Piotr Fryzlewicz and Markus Monnerjahn was at Version 3.9.6, 1999.

Author(s)

G P Nason

See Also

wd, wr.int, accessC, accessD, filter.select, plot.wd, threshold

Examples

# # Take the wd object generated in the examples to wd (called wds) # # Invert this wd object # # yans <- wr(wds) # # Compare it to the original, called y # # sum((yans-y)^2) # [1] 9.805676e-017 # # A very small number #


**Description**

Performs the inverse DWT for `wd3D.object`, i.e. 3D DWT objects.

**Usage**

```r
wr3D(obj)
```

**Arguments**

- `obj`: A `wd3D.object` 3D DWT object as returned by `wd3D`.

**Details**

The code implements a 3D version of Mallat’s inverse pyramid algorithm.

**Value**

A 3D array containing the inverse 3D DWT of `obj`.

**RELEASE**

Version 3.9.6 Copyright Guy Nason 1997

**Author(s)**

G P Nason

**See Also**

`wr`, `accessD.wd3D`, `print.wd3D`, `putD.wd3D`, `putDwd3Dcheck`, `summary.wd3D`, `threshold.wd3D`, `wd3D`, `wd3D.object`.

**Examples**

```r
# Now let's take the object generated by the last stage in the EXAMPLES
# section of threshold.wd3D and invert it!
#
#testwr <- wr3D(testwd3DT)
#
# You'll find that testwr is an array of dimension 8x8x8!
#```
wst  
Packet-ordered non-decimated wavelet transform.

Description
Computes the packet-ordered non-decimated wavelet transform (TI-transform). This algorithm is functionally equivalent to the time-ordered non-decimated wavelet transform (computed by `wd` with the type="station" argument).

Usage
```
wst(data, filter.number=10, family="DaubLeAsymm", verbose=FALSE)
```

Arguments
- `data`: A vector containing the data you wish to decompose. The length of this vector must be a power of 2.
- `filter.number`: This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments. Note: as of version 4.6 you can use the Lina-Mayrand complex-valued compactly supported wavelets.
- `family`: specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".
- `verbose`: Controls the printing of "informative" messages whilst the computations progress. Such messages are generally annoying so it is turned off by default.

Details
The packet-ordered non-decimated wavelet transform is more properly known as the TI-transform described by Coifman and Donoho, 1995. A description of this implementation can be found in Nason and Silverman, 1995.

The coefficients produced by this transform are exactly the same as those produced by the `wd` function with the type="station" option except in that function the coefficients are time-ordered. In the `wst` function the coefficients are produced by a wavelet packet like algorithm with a cyclic rotation step instead of processing with the father wavelet mirror filter at each level.

The coefficients produced by this function are useful in curve estimation problems in conjunction with the thresholding function `threshold.wst` and either of the inversion functions `AvBasis.wst` and `InvBasis.wst`. The coefficients produced by the time-ordered non-decimated wavelet transform are more useful for time series applications: e.g. the evolutionary wavelet spectrum computation performed by `ewspect`. Note that a time-ordered non-decimated wavelet transform object may be converted into a packet-ordered non-decimated wavelet transform object (and vice versa) by using the `convert` function.
Value

An object of class: wst. The help for the wst describes the intricate structure of this class of object.

RELEASE

Version 3.5.3 Copyright Guy Nason 1995

Author(s)

G P Nason

See Also

wst.object, threshold.wst, AvBasis.wst, InvBasis.wst, filter.select, convert, ewspect, plot.wst.

Examples

# Let's look at the packet-ordered non-decimated wavelet transform
# of the data we used to do the time-ordered non-decimated wavelet
# transform exhibited in the help page for wd.
#
test.data <- example.1()$y
#
# Plot it to see what it looks like (piecewise polynomial)
## Not run: ts.plot(test.data)
#
# Now let's do the packet-ordered non-decimated wavelet transform.
#
TDwst <- wst(test.data)
#
# And let's plot it....
#
## Not run: plot(TDwst)
#
# The coefficients in this plot at each resolution level are the same
# as the ones in the non-decimated transform plot in the wd
# help page except they are in a different order. For more information
# about how the ordering works in each case see
#
# Next examples
# "--------
# The chirp signal is also another good examples to use.
#
# Generate some test data
#
test.chirp <- simchirp()$y
## Not run: ts.plot(test.chirp, main="Simulated chirp signal")
# Now let's do the packet-ordered non-decimated wavelet transform.
# For a change let's use Daubechies extremal phase wavelet with 6
# vanishing moments (a totally arbitrary choice, please don't read
# anything into it).
#
# chirpwst <- wst(test.chirp, filter.number=6, family="DaubExPhase")
## Not run: plot(chirpwst, main="POND WT of Chirp signal")

wst.object

(Packet ordered) Nondecimated wavelet transform decomposition objects.

Description

These are objects of class wst. They represent a decomposition of a function with respect to a set of
(all possible) shifted wavelets.

Details

To retain your sanity we recommend that the coefficients from a wst object be extracted in one of
two ways:

- use getpacket.wst to obtain individual packets of either father or mother wavelet coefficients.
- use accessD.wst to obtain all mother coefficients at a particular resolution level.
- use accessC.wst to obtain all father coefficients at a particular resolution level.

You can obtain the coefficients directly from the wst$wp component (mother) or wst$Carray component (father) but you have to understand their organization described above.

Value

The following components must be included in a legitimate ‘wst’ object.

wp a matrix containing the packet ordered non-decimated wavelet coefficients. Each row of the matrix contains coefficients with respect to a particular resolution level. There are nlevelsWT(wst)+1 rows in the matrix. Row nlevels(wst)+1 (the “bottom”) row contains the “original” data used to produce the wavelet packet coefficients. Rows nlevels(wst) to row 1 contain coefficients at resolution levels nlevels(wst)-1 to 0 (so the first row contains coefficients at resolution level 0).

The columns contain the coefficients with respect to packets. A different packet length exists at each resolution level. The packet length at resolution level i is given by $2^i$. However, the getpacket.wst function should be used to access individual packets from a wst object.

Carray A matrix of the same dimensions and format as wp but containing the father wavelet coefficients.
The number of levels in the decomposition. If you raise 2 to the power of `nlevels` you get the number of data points used in the decomposition.

A list containing the details of the filter that did the decomposition (equivalent to the return value from the `filter.select` function).

The date that the transform was performed or the wst was modified.

**GENERATION**

This class of objects is returned from the `wst` function which computes the *packets-ordered* non-decimated wavelet transform (effectively all possible shifts of the standard discrete wavelet transform).

Many other functions return an object of class wst.

**METHODS**

The wst class of objects has methods for the following generic functions: `AvBasis`, `InvBasis`, `LocalSpec`, `MaNoVe`, `accessC`, `accessD`, `convert`, `draw`, `getpacket`, `image`, `nlevelsWT`, `nullevels`, `plot`, `print`, `putC`, `putD`, `putpacket`, `summary`, `threshold`.

**RELEASE**

Version 3.5.3 Copyright Guy Nason 1994

**Author(s)**

G P Nason

**See Also**

`wst`

---

**wst2D**

*(Packet-ordered) 2D non-decimated wavelet transform.*

**Description**

This function computes the (packet-ordered) 2D non-decimated wavelet transform

**Usage**

```r
wst2D(m, filter.number=10, family="DaubLeAsymm")
```
Arguments

\( m \) A matrix containing the image data that you wish to decompose. Each dimension of the matrix must be the same power of 2.

\( \text{filter.number} \) This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

\( \text{family} \) specifies the family of wavelets that you want to use. Two popular options are "DaubExPhase" and "DaubLeAsymm" but see the help for \( \text{filter.select} \) for more possibilities.

Details

The \( \text{wst2D} \) computes the (packet-ordered) 2D non-decimated discrete wavelet transform. Such a transform may be used in wavelet shrinkage of images using the \( \text{AvBasis.wst2D} \) function to perform an "average-basis" inverse. Such a transform was used to denoise images in the paper by Lang, Guo, Odegard, Burrus and Wells, 1995.

The algorithm works by mixing the HH, GH, HG and GG image operators of the 2D (decimated) discrete wavelet transform (see Mallat, 1989 and the implementation in WaveThresh called \( \text{imwd} \)) with the shift operator \( S \) (as documented in Nason and Silverman, 1995) to form new operators (as given in the help to \( \text{getpacket.wst2D} \)).

Subimages can be obtained and replaced using the \( \text{getpacket.wst2D} \) and \( \text{putpacket.wst2D} \) functions.

This function is a 2D analogue of the (packet-ordered) non-decimated discrete wavelet transform implemented in WaveThresh as \( \text{wst} \).

Value

An object of class \( \text{wst2D} \).

RELEASE

Version 3.9.5 Copyright Guy Nason 1998

Author(s)

G P Nason

See Also

\( \text{AvBasis.wst2D} \), \( \text{getpacket.wst2D} \), \( \text{imwd} \), \( \text{plot.wst2D} \), \( \text{print.wst2D} \), \( \text{putpacket.wst2D} \), \( \text{summary.wst2D} \), \( \text{wst2D.object} \).

Examples

```
# We shall use the lennon image.
#
data(lennon)
```
Now let's apply the (packet-ordered) 2D non-decimated DWT to it...

(Using the default wavelets)

```
uawst2D <- wst2D(lennon)
```

One can use the function `plot.wst2D` to get a picture of all the resolution levels. However, let's just look at them one at a time.

How many levels does our `uawst2D` object have?

```
nlevelsWT(uawst2D)
```

Let's look at resolution level 7.

```
## Not run: image(uawst2D$wst2D[8,,])
```

There are four main blocks here (each of 256x256 pixels) which themselves contain four sub-blocks. The primary blocks correspond to the no shift, horizontal shift, vertical shift and "horizontal and vertical" shifts generated by the shift $S$ operator. Within each of the 256x256 blocks we have the "usual" Mallat smooth, horizontal, vertical and diagonal detail, with the smooth in the top left of each block.

Let's extract the smooth, with no shifts at level 7 and display it.

```
## Not run: image(getpacket(uawst2D, level=7, index=0, type="S"))
```

Now if we go two more resolution levels deeper we have now 64x64 blocks which contain 32x32 subblocks corresponding to the smooth, horizontal, vertical and diagonal detail.

Groovy eh?

---

**wst2D.object**  
*(Packet ordered) Two-dimensional nondecimated wavelet transform decomposition objects.*

**Description**

These are objects of class `wst2D`. They represent a decomposition of a function with respect to a set of (all possible) shifted two-dimensional wavelets. They are a 2D extension of the `wst.object`.
Details

To retain your sanity we recommend that the coefficients from a `wst2D` object be extracted or replaced using

- `getpacket.wst2D` to obtain individual packets of either father or mother wavelet coefficients.
- `putpacket.wst2D` to insert coefficients.

You can obtain the coefficients directly from the `wst2D$wst2D` component but you have to understand their organization described above.

Value

The following components must be included in a legitimate `wst2D` object.

- **wst2D**
  This a three-dimensional array. Suppose that the original image that created the `wst2D` object is $n \times n$. Then the dimension of the `wst2D` array is $[nlevelsWT, 2n, 2n]$. The first index of the array refers to the resolution level of the array with "resolution level = index - 1" (so, e.g. the coarsest scale detailed is stored at index 1 and the finest at index `nlevels`). For a given resolution level (selected first index) the associated $2n \times 2n$ matrix contains the two-dimensional non-decimated wavelet coefficients for that level packed as follows.

  At the finest resolution level the $2n \times 2n$ coefficient image may be broken up into four $n \times n$ subimages. Each of the four images corresponds to data shifts in the horizontal and vertical directions. The top left image corresponds to "no shift" and indeed the top left image corresponds to the coefficients obtained using the decimated 2D wavelet transform as obtained using the `imwd` function. The top right image corresponds to a horizontal data shift; the bottom left to a vertical data shift and the bottom right corresponds to both horizontal and vertical data shift.

  Within each of the four $n \times n$ images named in the previous paragraph are again 4 subimages each of dimension $n/2 \times n/2$. These correspond to (starting at the top left and moving clockwise) the smooth (CC), horizontal detail (DC), diagonal detail (DD) and vertical detail (CD).

  At coarser resolution levels the coefficients are smaller submatrices corresponding to various levels of data shifts and types of detail (smooth, horizontal, vertical, diagonal).

  We strongly recommend the use of the `getpacket.wst2D` and `putpacket.wst2D` functions to remove and replace coefficients from `wst2D` objects.

- **nlevelsWT**
  The number of levels in the decomposition. If you raise 2 to the power of `nlevelsWT` you get the number of data points used in the decomposition.

- **filter**
  A list containing the details of the filter that did the decomposition (equivalent to the return value from the `filter.select` function).

- **date**
  The date that the transform was performed or the `wst2D` was modified.
GENERATION

This class of objects is returned from the `wst2D` function which computes the packets-ordered two-dimensional non-decimated wavelet transform (effectively all possible shifts of the standard two-dimensional discrete wavelet transform).

Many other functions return an object of class `wst2D`.

METHODS

The `wst2D` class of objects has methods for the following generic functions: `AvBasis`, `getpacket`, `plot`, `print`, `putpacket`, `summary`.

RELEASE

Version 3.5.3 Copyright Guy Nason 1994

Author(s)

G P Nason

See Also

`wst2D`

---

**wstCV**

Performs two-fold cross-validation estimation using packet-ordered non-decimated wavelet transforms and one, global, threshold.

Description


Usage

```r
wstCV(ndata, ll = 3, type = "soft", filter.number = 10, family = "DaubLeAsymm", tol = 0.01, verbose = 0, plot.it = FALSE, norm = l2norm, InverseType = "average", uvdev = madmad)
```

Arguments

- `ndata` the noisy data. This is a vector containing the signal plus noise. The length of this vector should be a power of two.
- `ll` the primary resolution for this estimation. Note that the primary resolution is *problem-specific*: you have to find out which is the best value.
- `type` whether to use hard or soft thresholding. See the explanation for this argument in the `threshold.wst` function.
filter.number  This selects the smoothness of wavelet that you want to use in the decomposition. By default this is 10, the Daubechies least-asymmetric orthonormal compactly supported wavelet with 10 vanishing moments.

family  specifies the family of wavelets that you want to use. The options are "DaubExPhase" and "DaubLeAsymm".

tol  the cross-validation tolerance which decides when an estimate is sufficiently close to the truth (or estimated to be so).

verbose  If TRUE then informative messages are printed during the progression of the function, otherwise they are not.

plot.it  If TRUE then a plot of the progress of optimising the error estimate for different values of the threshold is generated as the algorithm proceeds. The algorithm tries to minimize the error estimate so you should see a “bowl” developing. After each iteration the error estimate is plotted with the iteration number so you should see the numbers tend to the bottom of the bowl.

norm  which measure of distance to judge the dissimilarity between the estimates. The functions l2norm and linfnorm are suitable examples.

InverseType  The possible options are "average" or "minent". The former uses basis averaging to form estimates of the unknown function. The "minent" function selects a basis using the Coifman and Wickerhauser, 1992 algorithm to select a basis to invert.

uvdev  Universal thresholding is used to generate an upper bound for the ideal threshold. This argument provides the function that computes an estimate of the variance of the noise for use with the universal threshold calculation (see threshold.wst).

Details

This function implements the cross-validation method detailed by Nason, 1996 for computing an estimate of the error between an estimate and the “truth”. The difference here is that it uses the packet ordered non--decimated wavelet transform rather than the standard Mallat wd discrete wavelet transform. As such it is an examples of the translation-invariant denoising of Coifman and Donoho, 1995 but uses cross-validation to choose the threshold rather than SUREshrink.

Note that the procedure outlined above can use AvBasis basis averaging or basis selection and inversion using the Coifman and Wickerhauser, 1992 best-basis algorithm.

Value

A list returning the results of the cross-validation algorithm. The list includes the following components:

ndata  a copy of the input noisy data

xvwr  a reconstruction of the best estimate computed using this algorithm. It is the inverse (computed depending on what the InverseType argument was) of the xvwrWSTt component.

xvwrWSTt  a thresholded version of the packet-ordered non-decimated wavelet transform of the noisy data using the best threshold discovered by this cross-validation algorithm.
the universal threshold used as the upper bound for the algorithm that tries to
discover the optimal cross-validation threshold. The lower bound is always zero.

xvthresh: the best threshold as discovered by cross-validation. Note that this is one num-
ber, the global threshold. The wstCVt function should be used to compute a
level-dependent threshold.

xkeep: a vector containing the various thresholds used by the optimisation algorithm
in trying to determine the best one. The length of this vector cannot be pre-
determined but depends on the noisy data, thresholding method, and optimisa-
tion tolerance.

fkeep: a vector containing the value of the estimated error used by the optimisation
algorithm in trying to minimize the estimated error. The length, like that of
xkeep cannot be predetermined for the same reasons.

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Note

If plot.it is TRUE then a plot indicating the progression of the optimisation algorithm is plotted.

Author(s)

G P Nason

See Also

GetRSSWST, linfnorm, linfnorm, threshold.wst, wst, wst.object, wstCVt.

Examples

# Example PENDING
#

wstCVt Performs two-fold cross-validation estimation using packet-ordered
non-decimated wavelet transforms and a (vector) level-dependent
threshold.

Description

Performs Nason’s 1996 two-fold cross-validation estimation using packet-ordered non-decimated
wavelet transforms and a (vector) level-dependent threshold.
Usage

wstCVI(ndata, ll = 3, type = "soft", filter.number = 10, family = "DaubLeAsymm",
tol = 0.01, verbose = 0, plot.it = FALSE, norm = l2norm, InverseType = "average",
uvdev = madmad)

Arguments

ndata  the noisy data. This is a vector containing the signal plus noise. The length of
        this vector should be a power of two.
ll      the primary resolution for this estimation. Note that the primary resolution is
problem-specific: you have to find out which is the best value.
type    whether to use hard or soft thresholding. See the explanation for this argument
        in the threshold.wst function.
filter.number This selects the smoothness of wavelet that you want to use in the decomposi-
tion. By default this is 10, the Daubechies least-asymmetric orthonormal com-
        pactly supported wavelet with 10 vanishing moments.
family  specifies the family of wavelets that you want to use. The options are "DaubEx-
        Phase" and "DaubLeAsymm".
tol     the cross-validation tolerance which decides when an estimate is sufficiently
        close to the truth (or estimated to be so).
verbose If TRUE then informative messages are printed during the progression of the
        function, otherwise they are not.
plot.it Whether or not to produce a plot indicating progress.
norm    which measure of distance to judge the dissimilarity between the estimates. The
        functions l2norm and linfnorm are suitable examples.
InverseType The possible options are "average" or "minent". The former uses basis averaging
        to form estimates of the unknown function. The "minent" function selects a basis
        using the Coifman and Wickerhauser, 1992 algorithm to select a basis to invert.
uvdev   Universal thresholding is used to generate an upper bound for the ideal thresh-
        old. This argument provides the function that computes an estimate of the vari-
        ance of the noise for use with the universal threshold calculation (see threshold.wst).

Details

This function implements a modified version of the cross-validation method detailed by Nason,
1996 for computing an estimate of the error between an estimate and the “truth”. The difference
here is that it uses the packet ordered non-decimated wavelet transform rather than the standard
Mallat wd discrete wavelet transform. As such it is an examples of the translation-invariant de-
noising of Coifman and Donoho, 1995 but uses cross-validation to choose the threshold rather than
SUREshrink.

Further, this function computes level-dependent thresholds. That is, it can compute a different
threshold for each resolution level.

Note that the procedure outlined above can use AvBasis basis averaging or basis selection and
Value

A list returning the results of the cross-validation algorithm. The list includes the following components:

- **ndata**: a copy of the input noisy data
- **xvwr**: a reconstruction of the best estimate computed using this algorithm. It is the inverse (computed depending on what the InverseType argument was) of the **xvwrWSTt** component.
- **xvwrWSTt**: a thresholded version of the packet-ordered non-decimated wavelet transform of the noisy data using the best threshold discovered by this cross-validation algorithm.
- **uvt**: the universal threshold used as the upper bound for the algorithm that tries to discover the optimal cross-validation threshold. The lower bound is always zero.
- **xvthresh**: the best threshold as discovered by cross-validation. Note that this is vector, a level-dependent threshold with one threshold value for each resolution level. The first entry corresponds to level 1, the last entry corresponds to level nlevelsWST(ndata)-1 and the entries in between linearly to the levels in between. The **wstCV** function should be used to compute a global threshold.
- **optres**: The results from performing the optimisation using the nlminb function from Splus. This object contains many interesting components with information about how the optimisation went. See the nlminb help page for information.

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Author(s)

G P Nason

See Also

GetRSSWST, linfnorm, linfnorm, threshold.wst, wst, wst.object, wstCV

Examples

```#
# Example PENDING
#```
WTEnv

Environment that exists to store intermediate calculations for re-use within the same R session.

Description

Environment that stores results of long calculations so that they can be made available for immediate reuse.

Details

This environment is created on package load by wavethresh. The results of some intermediate calculations get stored in here (notably by PsiJ, PsiJmat and ipndacw). The reason for this is that the calculations are typically lengthy and it saves wavethresh time to search the WTEnv for pre-computed results. For example, ipndacw computes matrices of various orders. Matrices of low order form the upper-left corner of matrices of higher order so higher order matrix calculations can make use of the lower order instances.

A similar functionality was present in wavethresh in versions 4.6.1 and prior to this. In previous versions computations were saved in the users current data directory. However, the user was never notified about this nor permission sought.

The environment WTEnv disappears when the package disappears and the R session stops - and results of all intermediate calculations disappear too. This might not matter if you never use the larger objects (as it will not take much time to recompute).

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Author(s)

G P Nason

See Also

ipndacw, PsiJ, PsiJmat

Examples

#
# See what it is
#
WTEnv
#<environment: 0x102fc3830>
#
# Compute something that uses the environment
#
fred <- PsiJ(-5)
#
# Now let's see what got put in
#
ls(envir=WTEnv)
#[1] "Psi.5.10.DaubLeAsymm"

wvcvlrss  

**Computes estimate of error for function estimate.**

**Description**

This function is merely a call to the GetRSSWST function.

**Usage**

```r
wvcvlrss(threshold, ndata, levels, type, filter.number, family, norm,
verbose, InverseType)
```

**Arguments**

- **threshold**  
  the value of the threshold that you wish to compute the error of the estimate at
- **ndata**  
  the noisy data. This is a vector containing the signal plus noise. The length of
  this vector should be a power of two.
- **levels**  
  the levels over which you wish the threshold value to be computed (the thresh-
  old that is used in computing the estimate and error in the estimate). See the
  explanation for this argument in the `threshold.wst` function.
- **type**  
  whether to use hard or soft thresholding. See the explanation for this argument
  in the `threshold.wst` function.
- **filter.number**  
  This selects the smoothness of wavelet that you want to use in the decomposi-
  tion. By default this is 10, the Daubechies least-asymmetric orthonormal comp-
 actly supported wavelet with 10 vanishing moments.
- **family**  
  specifies the family of wavelets that you want to use. The options are "DaubEx-
  Phase" and "DaubLeAsymm".
- **norm**  
  which measure of distance to judge the dissimilarity between the estimates. The
  functions `l2norm` and `linfnorm` are suitable examples.
- **verbose**  
  If TRUE then informative messages are printed during the progression of the
  function, otherwise they are not.
- **InverseType**  
  The possible options are "average" or "minent". The former uses basis averaging
to form estimates of the unknown function. The "minent" function selects a basis
using the Coifman and Wickerhauser, 1992 algorithm to select a basis to invert.

**Details**

This function is merely a call to the GetRSSWST function with a few arguments interchanged. In particular, the first two arguments are interchanged. This is to make life easier for use with the `nlmnb` function which expects the first argument of the function it is trying to optimise to be the variable that the function is optimised over.
Value

A real number which is estimate of the error between estimate and truth at the given threshold.

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Author(s)

G P Nason

See Also

GetRSSWST.

Examples

#
# This function performs the error estimation step for the
# wstCVl function and so is not intended for
# user use.
#

wvmoments

Compute moments of wavelets or scaling function

Description

Numerically compute moments of wavelets or scaling function

Usage

wvmoments(filter.number = 10, family = "DaubLeAsymm", moment = 0, scaling.function = FALSE)

Arguments

filter.number The smoothness of wavelet or scaling function to compute moments for, see filter.select
family The wavelet family to use, see filter.select
moment The moment to compute
scaling.function If FALSE then a wavelet is used in the moment calculation, alternatively if TRUE the associated scaling function is used.
Details
Given a wavelet $\psi(x)$ this function computes the $m$th moment $\int x^m \psi(x) \, dx$.
Note that for low order moments the integration function often fails for the usual numerical reasons (this never happened in S!). It might be that fiddling with the tolerances will improve this situation.

Value
An object of class `integrate` containing the integral and other pieces of interesting information about the moments calculation.

Author(s)
G P Nason

See Also
draw.default

Examples
```
wmoments(filter.number=5, family="DaubExPhase", moment=5)
#-1.317600 with absolute error < 7.5e-05
```

Description
Prints out the release number of the WaveThresh package, and some copyright info.

Usage
```
wvrelease()
```

Arguments
None.

Details
Description says all

Value
Nothing

Author(s)
G P Nason
Examples

wvrelease()
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