EBImage

April 19, 2010

`denoise` *Blurring images*

Description

Blurs an image with ImageMagick functions.

Usage

```
blur(x, r=0, s=0.5)
gblur(x, r=0, s=0.5)
```

Arguments

`x`	An `Image` object or an array.
`r`	A numeric value for the radius of the pixel neighbourhood. The default value 0 enables automatic radius selection.
`s`	The standard deviation of the Gaussian filter used for blurring. For reasonable results, `r` must be larger than `s`.

Details

`blur` uses an unspecified separable kernel. `gblur` uses a Gaussian kernel. The algorithms used by these ImageMagick functions are not well defined and hence, the usage of `filter2` is preferable to `blur` or `gblur`.

Value

An `Image` object or an array, containing the blurred version of `x`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2005-2007

References

ImageMagick: http://www.imagemagick.org.

See Also

filter2

Examples

```
x = readImage(system.file("images", "lena.gif", package="EBImage"))
if (interactive()) display(x)

y = blur(x, r=3, s=2)
if (interactive()) display(y, title='blur(x, r=3, s=2)')

y = gblur(x, r=3, s=2)
if (interactive()) display(y, title='gblur(x, r=3, s=2)')
```

---

bwlabel *Binary segmentation*

Description

Labels connected (connected sets) objects in a binary image.

Usage

```
bwlabel(x)
```

Arguments

x	An Image object or an array. x is considered as a binary image, whose pixels of value 0 are considered as background ones and other pixels as foreground ones.

Details

All pixels for each connected set of foreground (non-zero) pixels in x are set to an unique increasing integer, starting from 1. Hence, max(x) gives the number of connected objects in x.

Value

An Grayscale Image object or an array, containing the labelled version of x.

Author(s)

Gregoire Pau, 2009

Examples

```
## simple example
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
if (interactive()) display(x, title='Binary')
y = bwlabel(x)
if (interactive()) display(normalize(y), title='Segmented')

## read nuclei images
```

```
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
if (interactive()) display(x)

## computes binary mask
y = thresh(x, 10, 10, 0.05)
y = opening(y, makeBrush(5, shape='disc'))
if (interactive()) display(y, title='Cell nuclei binary mask')

## bwlabel
z = bwlabel(y)
if (interactive()) display(normalize(z), title='Cell nuclei')
nbnuclei = apply(z, 3, max)
cat('Number of nuclei=', paste(nbnuclei, collapse=','),'\n')

## recolor nuclei in colors
cols = c('black', sample(rainbow(max(z))))
zrainbow = Image(cols[1+z], dim=dim(z))
if (interactive()) display(zrainbow, title='Cell nuclei (recolored)')
```

`channel` *Color and image color mode conversions*

Description

`channel` handles color space conversions between image modes. `rgbImage` combines `Grayscale` images into a `Color` one.

Usage

```
channel(x, mode)
rgbImage(red, green, blue)
```

Arguments

`x`	An `Image` object or an array.
`mode`	A character value specifying the target mode for conversion. See Details.
`red, green, blue`	`Image` objects in `Grayscale` color mode or arrays of the same dimension. If missing, a black image will be used.

Details

Conversion modes:

`rgb` Converts a `Grayscale` image or an array into a `Color` image, replicating RGB channels.

`gray, grey` Converts a `Color` image into a `Grayscale` image, using uniform 1/3 RGB weights.

`red, green, blue` Extracts the `red`, `green` or `blue` channel from a `Color` image. Returns a `Grayscale` image.

`asred, asgreen, asblue` Converts a `Grayscale` image or an array into a `Color` image of the specified hue.

channel changes the pixel intensities, unlike colorMode which just changes the way that EBImage should render an image,

Value

An Image object or an array.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>

See Also

colorMode

Examples

```
x = readImage(system.file("images", "shapes.png", package="EBImage"))
if (interactive()) display(x)
y = channel(x, 'asgreen')
if (interactive()) display(y)

## rgbImage
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
y = readImage(system.file('images', 'cells.tif', package='EBImage'))
if (interactive()) display(x, title='Cell nuclei')
if (interactive()) display(y, title='Cell bodies')

cells = rgbImage(green=1.5*y, blue=x)
if (interactive()) display(cells, title='Cells')
```

Combine *Combining images*

Description

Merges images to create image sequences.

Usage

```
combine(x, ..., along)
```

Arguments

x	An Image object, an array, or a list of Image objects and arrays.
...	Image objects or arrays.
along	an optional numeric. See details.

Details

The function `combine` uses `abind` to merge multi-dimensionnal arrays along the dimension specified by the value `along`.

If `along` is missing, a default value depending on the color mode of `x` is used. If `x` is a `Grayscale` image or an array, `along` is set to 3 and image objects are combined on this dimension. If `x` is a `Color` image, `along` is set to 4 and image objects are combined on this dimension, leaving room on the third dimension for color channels.

Value

An `Image` object or an array.

Author(s)

Gregoire Pau

See Also

`Image`

Examples

```
if (interactive()) {
  ## combination of color images
  lena = readImage(system.file("images", "lena-color.png", package="EBImage"))
  x = combine(lena, flip(lena), flop(lena))
  if (interactive()) display(x)

  ## Blurred lenas
  x = resize(lena, 128, 128)
  xt = list()
  for (t in seq(0.1, 5, len=9)) xt=c(xt, list(blur(x, s=t)))
  xt = combine(xt)
  if (interactive()) display(xt, title='Blurred Lenas')
}
```

`display` *Interactive image display*

Description

Display images.

Usage

```
display(x, no.GTK, main, colorize,
        title = paste(deparse(substitute(x))),
        useGTK = TRUE)
animate(x)
```

Arguments

x	An Image object or an array.
useGTK	A logical of length 1. See details.
title	Window title.
no.GTK, main, colorize	Deprecated.

Details

By default (and if available), the display function uses GTK to open a window and display the image. Multiple windows can be opened in this way.

If GTK is not available or if useGTK is FALSE, ImageMagick is used; only one window at a time can be open, and it needs to be closed by the user interactively before the next window can be opened. The ImageMagick display is not available on MS-Windows.

The animate function shows an animated sequence of images and uses ImageMagick. Similar limitations as for display apply (only one window, not on MS-Windows.)

Value

The functions are called for their side effect. Return value is invisible NULL.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>

References

ImageMagick: http://www.imagemagick.org GTK: http://www.gtk.org, on MS-Windows http://gladewin32.sf.net

Examples

```
## single image
lena = readImage(system.file("images", "lena-color.png", package="EBImage"))
if (interactive()) display(lena)

## animated threshold
x = readImage(system.file("images", "lena-color.png", package="EBImage"))
x = resize(x, 128, 128)
xt = list()
for (t in seq(0.1, 5, len=9)) xt=c(xt, list(blur(x, s=t)))
xt = combine(xt)
if (interactive()) display(xt, title='Blurred Lenas')
```

distmap *Distance map transform*

Description

Computes the distance map transform of a binary image. The distance map is a matrix which contains for each pixel the distance to its nearest background pixel.

Usage

```
distmap(x, metric=c('euclidean', 'manhattan'))
```

Arguments

x	An Image object or an array. x is considered as a binary image, whose pixels of value 0 are considered as background ones and other pixels as foreground ones.
metric	A character indicating which metric to use, L1 distance (manhattan) or L2 distance (euclidean). Default is euclidean.

Details

A fast algorithm of complexity O(M*N*log(max(M,N))), where (M,N) are the dimensions of x, is used to compute the distance map.

Value

An Image object or an array, with pixels containing the distances to the nearest background points.

Author(s)

Gregoire Pau, <gpau@ebi.ac.uk>, 2008

References

M. N. Kolountzakis, K. N. Kutulakos. Fast Computation of the Euclidean Distance Map for Binary Images, Infor. Proc. Letters 43 (1992).

Examples

```
x = readImage(system.file("images", "shapes.png", package="EBImage"))
if (interactive()) display(x)
dx = distmap(x)
if (interactive()) display(dx/10, title='Distance map of x')
```

drawtext *Draw text on images.*

Description

Draws text on images.

Usage

```
drawtext(img, xy, labels, font, col)

drawfont(family=switch(.Platform$OS.type, windows="Arial", "helvetica"),
         style="n", size=14, weight=200, antialias=TRUE)
```

Arguments

img	An Image object or an array.
xy	Matrix (or a list of matrices if img contains multiple frames) of coordinates of labels.
labels	A character vector (or a list of vectors if img contains multiple frames) containing the labels to be output.
font	A font object, returned by drawfont. If missing, a default OS-dependent font will be chosen.
col	A character vector of font colors.
family	A character value indicating the font family to use. Valid examples on Linux/UNIX systems include helvetica, times, courier and symbol. Valid examples on Windows machines include TrueType like Arial and Verdana.
style	A character value specifying the font style to use. Supported styles are: normal (default), italic, and oblique.
size	Font size in points.
weight	A numeric value indicating the font weight (bold font). Supported values range between 100 and 900.
antialias	A logical value indicating whether the font should be anti-aliased.

Value

An Image object or an array, containing the transformed version of img.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

Examples

```
lena = readImage(system.file("images", "lena-color.png", package="EBImage"))
font = drawfont(weight=600, size=28)
lena = drawtext(lena, xy=c(250, 450), labels="Lena", font=font, col="white")
if (interactive()) display(lena)
```

EBImage-deprecated *EBImage deprecated functions*

Description

These following functions are deprecated and will be defunct in the next Bioconductor release.

- frameDist, matchObjects
- stopIfNotImage, morphKern
- mkbox, mkball
- header, assert
- chooseImage
- resample, sharpen, umask, modulate
- negate, affinet, normalize2, noise
- mediansmooth, cgamma, enhance, denoise
- contrast, despeckle, edge, segment
- cthresh, athresh
- channelMix

EBImage *Package overview*

Description

EBImage is an image processing and analysis package for R. Its primary goal is to enable automated analysis of large sets of images such as those obtained in high throughput automated microscopy.

The package uses the ImageMagick library for image I/O operations and some image processing methods. The GTK library is used for displaying images using display.

EBImage relies on the Image object to store and process images but also works on multi-dimensional arrays.

Package content

Image methods

- Image
- as.Image, is.Image
- colorMode, imageData
- getNumberOfFrames

Image I/O, display

- readImage, writeImage
- display, animate

- image

Spatial transform

- resize, flip, flop
- rotate, translate

Image segmentation, objects manipulation

- thresh, bwlabel
- watershed, propagate
- ocontour
- paintObjects, rmObjects, reenumerate

Image enhancement, filtering

- normalize
- filter2, blur, gblur
- equalize

Morphological operations

- makeBrush
- erode, dilate, opening, closing
- distmap
- floodFill, fillHull

Colorspace manipulation

- rgbImage, channel

Image stacking, combining, tiling

- stackObjects
- combine
- tile, untile

Drawing on images

- drawfont, drawtext

Features extraction

- getFeatures
- hullFeatures
- edgeProfile, edgeFeatures
- moments, cmoments, smoments, rmoments
- haralickFeatures, haralickMatrix
- zernikeMoments

Deprecated

- frameDist, matchObjects
- stopIfNotImage

- morphKern, mkbox, mkball
- header, assert
- chooseImage
- resample, sharpen, umask, modulate
- negate, affinet, normalize2, noise
- mediansmooth, cgamma, enhance, denoise
- contrast, despeckle, edge, segment
- cthresh, athresh
- channelMix

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Examples

```
example(readImage)
example(display)
example(rotate)
example(propagate)
```

equalize *Histogram equalization*

Description

Equalize the histogram of an image.

Usage

```
equalize(x)
```

Arguments

x	An Image object or an array.

Details

The algorithm used by this ImageMagick function is not well defined.

Value

An Image object or an array, containing the transformed version of x.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

References

ImageMagick: http://www.imagemagick.org.

Examples

```
x = readImage(system.file("images", "lena.gif", package="EBImage"))
if (interactive()) display(x)

y = equalize(x)
if (interactive()) display(y, title='equalize(x)')
```

edgeFeatures *Extraction of edge profiles and edge features from image objects*

Description

Extract the edge profile from image objects, computing for each object the distances of edge points to the object geometric center, at different rotation angles.

Usage

```
edgeFeatures(x, ref)
edgeProfile(x, ref, n=32, fft=TRUE, scale=TRUE, rotate=TRUE)
```

Arguments

x	An Image object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
ref	An Image object or an array, containing the intensity values of the objects.
n	An integer value giving the number of angle measures. The full circle of [-pi,pi] is divided into n-1 segments, at which edges the profile is approximated.
fft	A logical value. If TRUE, the resulting profile is the fft transformation of the distance profile giving the frequences of angular changes in shape.
scale	A logical value. If TRUE, the resulting profile is scaled by the effective radius (calcualted as part of link{hull.features}) making the profile scale invariant.
rotate	A logical value. If TRUE, the resulting profile is shifted by the object's roation angle (calculated from the moments on the ref image, if provided, and on the hull otherwise.

Details

edgeFeatures returns the following features:

- e.irr: difference between the smallest and largest distance profile values.
- e.f2Pi: 2pi/1 frequency component of the distance profile.
- e.fPi: 2pi/2 frequency component of the distance profile.
- e.f2Pi3: 2pi/3 frequency component of the distance profile.
- e.fPi2: 2pi/4 frequency component of the distance profile.

Value

edgeFeatures returns a matrix (or a list of matrices if x contains multiple frames) of features computed of the objects present in x and using the intensity values of ref.

edgeProfile returns a matrix ((or a list of matrices if x contains multiple frames) of profile values, corresponding, from left to right, to the equidistant divisions of the range [-pi,pi] if fft is FALSE. Otherwise, the matrix contains the FFT transform of the corresponding distance profile.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

See Also

getFeatures, ocontour

Examples

```
example(getFeatures)
```

`haralickMatrix` *Co-occurrence matrices (GLCM) and Haralick texture features*

Description

Computes the gray level co-occurrence matrix (GLCM, frequency of pixel intensities given the mean intensity of their 4 neighbouring pixels) and corresponding Haralick features from image objects.

Usage

```
haralickFeatures(x, ref, nc = 32)
haralickMatrix(x, ref, nc = 32)
```

Arguments

`x`	An `Image` object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
`ref`	An `Image` object or an array, containing the intensity values of the objects.
`nc`	A numeric value. Specifies the number of gray levels used to compute the co-occurrence matrix. Default value is 32.

Details

`haralickFeatures` computes the following set of statistics on the GLCM matrix:

- `h.asm`Angular second moment: `sum[i=1^nc] sum[j=1^nc]p(i,j)^2`.
- `h.con`Contrast: `sum[i=2^(2*nc)] n^2 * sum[i=1^nc] sum[j=1^nc] p(i,j), for all i,j s.t ABS(i - j) = n`.
- `h.cor`Correlation: `sum[i=1^nc] sum[j=1^nc]((i * j) * p(i,j) - mu_x * mu_y) / sigma_x * sigma_y`.
- `h.var`Variance: `sum[i=1^nc] sum[j=1^nc](i - mu)^2. * p(i,j)`.
- `h.idm`Inverse difference moment: `sum[i=1^nc] sum[j=1^nc] p(i,j) / (1 + (i - j)^2)` .
- `h.sav`Sum average: `sum[i=2^(2*nc)] i * Px+y(i)`.
- `h.sva`Sum variance: `sum[i=2^(2*nc)] (i - sen)^2 * Px+y(i)`.
- `h.sen`Sum entropy: `-sum[i=2^(2*nc)] Px+y(i) * log(p(i,j))`.
- `h.ent`Entropy: `-sum[i=1^nc] sum[j=1^nc] p(i,j) * log( p(i,j) )`.
- `h.dva`Difference variance: `sum[i=0^(nc-1)] (i^2) * Px-y(i)`.
- `h.den`Difference entropy: `sum[i=0^(nc-1)] Px-y(i) * log( Px-y(i,j) )`.
- `h.f12`Measure of correlation: `abs(ent - HXY1) / HX`.
- `h.f13`Measure of correlation: `sqrt( 1 - exp(2*(ent - HXY2)))`.

where:

- `p`is the GLCM matrix.
- `Px(i)` Marginal frequency. Defined by `Px(i) = sum[j=1^nc] p(i,j)`.

- `Py(j)` Marginal frequency. Defined by `Py(j) = sum[i=1^nc] p(i,j)`.
- `mu_x, mu_y` Means of `Px` and `Px`.
- `sigma_x, sigma_y` Standard deviations of `Px` and `Py`.
- `Px+y` Probability of the co-occurrence matrix coordinates sums to `x+y`. Defined by `Px+y(k) = sum[i=1^nc] sum[j=1^nc] p(i,j), i + j = k and k = 2,3,...,2*nc`.
- `Px-y` Probability of the absolute value of the difference between co-occurrence matrix coordinates being equal to `x-y`. Defined by `Px-y(k) = sum[i=1^nc] sum[j=1^nc] p(i,j), abs(i - j) = k and k = 2,3,...,2*nc`.
- `HXY1` `-sum[i=1^nc] sum[j=1^nc] p(i,j) * log( Px(i),Py(j)).`
- `HXY2` `-sum[i=1^nc] sum[j=1^nc] Px(i)*Py(j) * log( Px(i),Py(j)).`

Computed Haralick features are rotational invariant and good descriptors of object textures.

Value

`haralickFeatures` returns a matrix (or a list of matrices if `x` contains multiple frames) of features computed of the objects present in `x` and using the intensity values of `ref`.

`haralickMatrix` returns an array (or a list of arrays if `x` contains multiple frames) of dimension `nc*nc*nobj`, where `nobj` is the number of objects in `x`, containing the GLCM values of image objects.

Author(s)

Mike Smith, <msmith@ebi.ac.uk>; Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

References

R. M. Haralick, K Shanmugam and Its'Hak Deinstein (1979). *Textural Features for Image Classification*. IEEE Transactions on Systems, Man and Cybernetics.

See Also

`getFeatures`, `zernikeMoments`

Examples

```
example(getFeatures)
```

`hullFeatures` *Extraction of hull features from image objects*

Description

Computes hull features from image objects.

Usage

```
hullFeatures(x)
```

Arguments

x	An Image object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.

Details

Extracted object features are:

- g.x ,g.y - coordinates of the geometric center.
- g.s - size in pixels.
- g.p - perimeter in pixels.
- g.pdm - mean distance from the center to perimeter.
- g.pdsd - standard deviation of the distance to perimeter.
- g.effr - effective radius (is the radius of a circle with the same area).
- g.acirc - acircularity (fraction of pixels outside of the circle with radius g.effr).
- g.sf - shape factor, equals to (g.p/ (2*sqrt(i*g.s))).
- g.edge - number of pixels at the edge of the image.
- g.theta - hull orientation angle, in radians. See above.
- g.l1 - largest eigeinvalue of the covariance matrix. See above.
- g.l2 - lowest eigenvalue of the covariance matrix. See above.
- g.ecc - eccentricity, equals to $sqrt(1 - g.l2/g.l1)$. See above.
- g.I1, g.I2 - first and second Hu's translation/scale/rotation invariant moment. See above.

The features g.theta, g.l1, g.l2, g.ecc, g.I1, g.I2 are computed with the function moments using the binary objects as intensity values, e.g. g.theta = moment(x,x>0)[, 'm.theta']. See moments for details on properties of these features.

Value

A matrix (or a list of matrices if x contains multiple frames) of features computed of the objects present in x.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

See Also

moments, getFeatures

Examples

```
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
y = bwlabel(x)
if (interactive()) display(normalize(y), title='Objects')

## hullFeatures
hf = hullFeatures(y)
print(hf)
```

`moments` *Image moments and moment invariants*

Description

Computes moments and invariant moments from image objects.

Usage

```
moments(x, ref)
cmoments(x, ref)
rmoments(x, ref)
smoments(x, ref, pw=3, what="scale")
```

Arguments

`x`	An `Image` object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
`ref`	An `Image` object or an array, containing the intensity values of the objects.
`pw`	A numeric value specifying the maximum moment order to compute. Default is 3.
`what`	A character string partially matching `central` or `scale`, specifiying what kind of moments to compute. Default is `scale`.

Details

`moments` returns the features returned by `cmoments`, `rmoments` and the features `m.n20`, `m.n11`, `m.n02`, `m.theta`, `m.l1`, `m.l2` and `m.ecc` for each objet. See `Definitions` for details on features.

`cmoments` returns the features `m.pxs`, `m.int`, `m.x` and `m.y` for each objet.

`rmoments` returns Hu's translation/rotation/scale 7 invariant moments `m.Ik` for each object, where k spans from 1 to 7.

`smoments` returns for each object the central moments mu_pq if `what=central` or the scale invariant moments nu_pq if `what=scale`. The variables (p, q) span the range [0, pw].

Value

`moments`, `cmoments` and `rmoments` returns a matrix (or a list of matrices if `x` contains multiple frames) of features computed of the objects present in `x` and using the intensity values of `ref`.

`smoments` returns a 3-dimensional array of size (`pw+1`, `pw+1`, `n`) where `n` is the maximal value of `x`, or a list of such arrays if `x` contains multiple frames.

Definitions

Image moments m_pq are defined for the k-th object in `x` by: $m_pq = sum_{i,jst.x_ij=k} i^p * j^q * ref_ij$.

Central moments mu_pq are defined for the k-th object in `x` by: $mu_{pq} = sum_{i,jst.x_ij=k}(i - m_10/m_00)^p * (j - m_01/m_00)^q * ref_{ij}$. Central moments are invariant by translation.

Scale moments nu_pq are defined for the k-th object in `x` by: $nu_{pq} = mu_pq/mu_00^(1 + (p + q)/2)$. Scale moments are invariant by translation and scaling.

Features returned by `moments`, `cmoments` and `rmoments` are defined by:

- `m.pxs` = $sum_{i,jst.x_ij=k}1$
- `m.int` = $m_0 0$
- `m.x` = $m_1 0/m_0 0$
- `m.y` = $m_0 1/m_0 0$
- `m.n20` = $nu_2 0$
- `m.n11` = $nu_1 1$
- `m.n02` = $nu_0 2$
- `m.theta` = $0.5 * atan(2 * mu_1 1/(mu_2 0 - mu_0 2))$
- `m.l1` = largest eigenvalue of the covariance matrix [$mu_2 0$, $mu_1 1$; $mu_1 1$, $mu_0 2$]/$m_0 0$
- `m.l2` = smallest eigenvalue of the covariance matrix
- `m.ecc` = $sqrt(1 - m.l2/m.l1)$
- `m.Ik` = k-th Hu's moment, see References.

Properties:

- `m.pxs` is the surface of the objects, in pixels.
- `m.int` is the mass of the object.
- (`m.x`, `m.y`) is the center of gravity of the object.
- `m.n20`, `m.n11` and `m.n02` are translation/scale invariant moments.
- `m.theta` characterizes the orientation of an object in radians.
- 2*sqrt(`m.l1`) and 2*sqrt(`m.l2`) are the semi-major and semi-minor axes of the object and have the dimension of a length.
- `m.Ik` is the translation/scale/rotation invariant k-th Hu's moment.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

References

M. K. Hu, *Visual Pattern Recognition by Moment Invariants*, IRE Trans. Info. Theory, vol. IT-8, pp.179-187, 1962

Image moments: http://en.wikipedia.org/wiki/Image_moments

See Also

`getFeatures`, `bwlabel`, `watershed`, `propagate`

Examples

```
## load cell nucleus images
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
if (interactive()) display(x)

## computes object mask
y = thresh(x, 10, 10, 0.05)
y = opening(y, makeBrush(5, shape='disc'))
mask = fillHull(bwlabel(y))
if (interactive()) display(mask, title='Cell nuclei')
```

```
## moments
m = moments(mask, x)
mc = do.call(rbind, m)
print(mc[1:5,])
cat('Mean nucleus size is', mean(mc[,'m.pxs']), '\n')
cat('Mean nucleus eccentricity is', mean(mc[,'m.ecc']), '\n')

## paint nuclei with an eccentricity higher than 0.85
maskb = mask
for (i in 1:dim(mask)[3]) {
  id = which(m[[i]][,'m.ecc']<0.85)
  z = maskb[,,i]
  z[!is.na(match(z, id))] = 0
  maskb[,,i] = z
}
img = paintObjects(maskb, channel(x, 'rgb'), col=c(NA, 'red'), opac=c(0,0.7))
if (interactive()) display(img, title='Nuclei with high eccentricity')
```

`zernikeMoments` *Extraction of Zernike moments from image objects.*

Description

Computation of Zernike moment features from image objects.

Usage

```
zernikeMoments(x, ref, N = 12, R = 30, apply.Gaussian, pseudo)
```

Arguments

`x`	An `Image` object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
`ref`	An `Image` object or an array, containing the intensity values of the objects.
`N`	A numeric. Indicates the maximal order of Zernike polynomials to be computed. Default value is 12.
`R`	A numeric. Defines the radius of the circle in pixels around object centers from which the features are calculated.
`apply.Gaussian, pseudo`	Deprecated.

Details

Zernike features are computed by projecting image objects on the Zernike complex polynomials, using:

`z.{nl} = (n+1) / pi * abs( sum_x,y(V*nl(x,y) * i(x,y)) ),`

where `0 <= l <= n, n - l` is even and `i(x,y)` is the intensity of the reference image at the coordinates `(x,y)` that fall withing a circle of radius `R` from the object's centre. Coordinates are taken relative to the object's centre.

`V*nl` is a complex conjugate of a Zernike polynomial of degree `n` and angular dependence `l`:

`Vnl(x,y) = Qnl(x,y) * exp(j*l*theta)`, where `j = sqrt(-1), theta=atan2(y,x)`, and

`Qnl(x,y) = sum[_m=0^((n-l)/2)] ((-1)^m * (n-m)! * r^(n-2*m)) / (m! * ((n-2*m+l)/2)! * ((n-2*m-l)/2)!)` , where `r = sqrt(x^2+y^2)`.

Value

Returns a matrix (or a list of matrices if `x` contains multiple frames) of features computed of the objects present in `x` and using the intensity values of `ref`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>; Mike Smith, <msmith@ebi.ac.uk>, 2007

References

F. Zernike. *Beugungstheorie des Schneidenverfahrens und seiner verbesserten Form, der Phasenkontrastmethode (Diffraction theory of the cut procedure and its improved form, the phase contrast method)*. Physica, 1:pp. 689-704, 1934.

Jamie Shutler, *Complex Zernike Moments*: http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/SHUTLER3/node11.html

See Also

`getFeatures`

Examples

```
example(getFeatures)
```

---

fillHull *Fill holes in objects*

Description

Fill holes in objects.

Usage

```
fillHull(x)
```

Arguments

`x`	An `Image` object or an array.

Details

`fillHull` fills holes in the objects defined in `x`, where objects are sets of pixels with the same unique integer value.

Value

An Image object or an array, containing the transformed version of x.

Author(s)

Gregoire Pau, Oleg Sklyar; 2007

See Also

bwlabel

Examples

```
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
if (interactive()) display(x)

y = thresh(x, 10, 10, 0.05)
if (interactive()) display(y, title='Cell nuclei')

y = fillHull(y)
if (interactive()) display(y, title='Cell nuclei without holes')
```

---

filter2 *2D Convolution Filter*

Description

Filters an image using the fast 2D FFT convolution product.

Usage

```
filter2(x, filter)
```

Arguments

x	An Image object or an array.
filter	An Image object or an array, with odd spatial dimensions. Must contain only one frame.

Details

Linear filtering is useful to perform low-pass filtering (to blur images, remove noise...) and high-pass filtering (to detect edges, sharpen images). The function makeBrush is useful to generate filters.

Data is reflected around borders.

If x contains multiple franes, the filter will be applied one each frame.

Value

An Image object or an array, containing the filtered version of x.

Author(s)

Gregoire Pau, <gpau@ebi.ac.uk>

See Also

makeBrush, convolve, fft, blur

Examples

```
x = readImage(system.file("images", "lena-color.png", package="EBImage"))
if (interactive()) display(x, title='Lena')

## Low-pass disc-shaped filter
f = makeBrush(21, shape='disc', step=FALSE)
if (interactive()) display(f, title='Disc filter')
f = f/sum(f)
y = filter2(x, f)
if (interactive()) display(y, title='Filtered lena')

## High-pass Laplacian filter
la = matrix(1, nc=3, nr=3)
la[2,2] = -8
y = filter2(x, la)
if (interactive()) display(y, title='Filtered lena')
```

---

floodFill *Region filling*

Description

Fill regions in images.

Usage

```
floodFill(x, pt, col, tolerance=0)
```

Arguments

x	An Image object or an array.
pt	Coordinates of the start filling point.
col	Fill color. This argument should be a numeric for Grayscale images and an R color for Color images.
tolerance	Color tolerance used during the fill.

Details

Flood fill is performed using the fast scan line algorithm. Filling starts at pt and grows in connected areas where the absolute difference of the pixels intensities (or colors) remains below tolerance.

Value

An Image object or an array, containing the transformed version of x.

Author(s)

Gregoire Pau, Oleg Sklyar; 2007

Examples

```
x = readImage(system.file("images", "shapes.png", package="EBImage"))
y = floodFill(x, c(67, 146), 0.5)
if (interactive()) display(y)

y = channel(y, 'rgb')
y = floodFill(y, c(48, 78), 'red')
y = floodFill(y, c(156, 52), 'orange')
if (interactive()) display(y)

x = readImage(system.file("images", "lena.gif", package="EBImage"))
y = floodFill(x, c(226, 121), 1, tolerance=0.1)
if (interactive()) display(y)
```

---

getFeatures *Extract feature extraction from image objects*

Description

Extracts numerical features from image objects.

Usage

```
getFeatures(x, ref, N=12, R=30, apply.Gaussian, nc=32, pseudo)
```

Arguments

x	An Image object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
ref	An Image object or an array, containing the intensity values of the objects.
N	Passed to zernikeMoments. Integer value defining the degree of the Zernike polynomials, which in turn defines the number of features calculated. Defaults to 12.
R	Passed to zernikeMoments. Defines the radius of the circle around an object centre from which the features are calculated. See details. Defaults to 30.
nc	Passed to haralickFeatures. A numeric value. Specifies the number of gray levels to bin ref into when computing the co-occurrence matrix. Defaults to 32.
apply.Gaussian, pseudo	Deprecated.

Details

Combines and returns the features returned by hullFeatures, moments, edgeFeatures, haralickFeatures and zernikeMoments.

Value

`getFeatures` returns feature matrices.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

See Also

`hullFeatures`, `moments`, `edgeFeatures` `haralickFeatures`, `zernikeMoments`

Examples

```
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
x = x[,,1]
if (interactive()) display(x)

## computes object mask
y = thresh(x, 10, 10, 0.05)
y = opening(y, makeBrush(5, shape='disc'))
mask = bwlabel(y)
if (interactive()) display(mask, title='Cell nuclei')

## features
ftrs = getFeatures(mask, x)[[1]]
print(ftrs[1:5,])

## paint nuclei with an eccentricity higher than 0.85
maskb = mask
id = which(ftrs[,'m.ecc']<0.85)
maskb[!is.na(match(maskb, id))] = 0

img = paintObjects(maskb, channel(x, 'rgb'), col='red')
if (interactive()) display(img, title='Nuclei with high eccentricity')
```

`Image` *Image class*

Description

The package `EBImage` uses the class `Image` to store and process images. Images are stored as multi-dimensional arrays containing the pixel intensities. The class `Image` extends the base class `array` and uses the `colormode` slot to store how the color information of the multi-dimensional data is handled.

The `colormode` slot could be either `Grayscale` or `Color`. In both modes, the two first dimensions of the underlying array are understood to be the spatial dimensions of the image. In the `Grayscale` mode, the remaining dimensions contain other images. In the the `Color` mode, the third dimension contains the red, green and blue channels of the image and the remaining dimensions contain other images. The color mode `TrueColor` exists but is deprecated.

All methods of the package `EBImage` works either with `Image` objects or multi-dimensional arrays but in the latter case, the color mode is assumed to be `Grayscale`.

Usage

```
Image(data, dim, colormode)
as.Image(x)
is.Image(x)

colorMode(y)
colorMode(y) <- value

imageData(y)
imageData(y) <- value

getNumberOfFrames(y, type='total')
```

Arguments

data	A vector or array containing the pixel intensities of an image. If missing, a default 1x1 null array is used.
dim	A vector containing the final dimensions of an Image object. If missing, equals to dim(data).
colormode	A numeric or a character string containing the color mode which could be either Grayscale or Color. If missing, equals to Grayscale.
x	An R object.
y	An Image object or an array.
value	For colorMode, a numeric or a character string containing the color mode which could be either Grayscale or Color. For imageData, an Image object or an array.
type	A character string containing total or render. If missing, equals to total.

Details

Depending of type, getNumberOfFrames returns the total number of frames contained in the object y or the number of renderable frames. The total number of frames is independent of the color mode and is equal to the product of all the dimensions except the two first ones. The number of renderable frames is equal to the total number of frames in the Grayscale color mode and is equal to the product of all the dimensions except the three first ones in the Color color mode.

Value

Image and as.Image return a new Image object.

is.Image returns TRUE if x is an Image object and FALSE otherwise.

colorMode returns the color mode of y and colorMode<- changes the color mode of y.

imageData returns the array contained in an Image object.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2005-2007

See Also

readImage, display

Examples

```
s1 = exp(12i*pi*seq(-1, 1, length=300)^2)
y = Image(outer(Im(s1), Re(s1)))
if (interactive()) display(normalize(y))

x = Image(rnorm(300*300*3),dim=c(300,300,3), colormode='Color')
if (interactive()) display(x)

w = matrix(seq(0, 1, len=300), nc=300, nr=300)
m = abind(w, t(w), along=3)
z = Image(m, colormode='Color')
if (interactive()) display(normalize(z))

y = Image(c('red', 'violet', '#ff51a5', 'yellow'), dim=c(71, 71))
if (interactive()) display(y)

## colorMode example
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
x = x[,,1:3]
if (interactive()) display(x, title='Cell nuclei')
colorMode(x)=Color
if (interactive()) display(x, title='Cell nuclei in RGB')
```

---

readImage *Image I/O*

Description

Functions to read and write images from/to files and URL's. The supported image formats depend on the capabilities of ImageMagick.

Usage

```
readImage(files, colormode)
writeImage(x, files, quality = 100)
```

Arguments

files	A character vector of file names or URLs. If missing, an interactive file chooser is displayed.
x	An Image object or an array.
quality	A numeric, ranging from 1 to 100. Default is 100.
colormode	Deprecated.

Details

When writing images in formats supporting lossy compression (like JPEG), the quality can be specified used a quality value in the range [1,100]. The best quality is obtained with 100.

The file format is deduced from the file name extension.

ImageMagick is used to perform all image I/O operations. Therefore, the package supports all the file types supported by ImageMagick.

When reading images, files of different formats can be mixed in any sequence, including mixing single 2D images with TIFF image stacks. The result will contain a stack with all images and stacks, at the size of the first image read. Subsequent images are cropped (if larger) or filled with background (if smaller).

Value

`readImage` returns a new `Image` object. `writeImage` returns `invisible(files)`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2005-2006

References

ImageMagick: http://www.imagemagick.org

Examples

```
## Reads and display images
f = system.file("images", "lena-color.png", package="EBImage")
x = readImage(f)
if (interactive()) display(x)

x = readImage(system.file("images", "nuclei.tif", package="EBImage"))
if (interactive()) display(x)

try({
  im = readImage("http://www.google.com/intl/en/images/logo.gif")
  if (interactive()) display(im)
})

## Converts a TIFF file into JPEG
f1 = system.file("images", "lena-color.png", package="EBImage")
x1 = readImage(f1)
f2 = paste(tempfile(), "jpeg", sep=".")
writeImage(x1, f2)
cat("Converted '", f1, "' into '", f2, "'.\n", sep='')
```

---

morphology *Perform morphological operations on images*

Description

Functions to perform morphological operations on binary images.

Usage

```
dilate(x, kern, iter)
erode(x, kern, iter)
opening(x, kern, iter)
closing(x, kern, iter)

makeBrush(size, shape=c('box', 'disc', 'diamond'), step=TRUE)
```

Arguments

x	An Image object or an array. x is considered as a binary image, whose pixels of value 0 are considered as background ones and other pixels as foreground ones.
kern	An Image object or an array, containing the structuring element. kern is considered as a binary image, whose pixels of value 0 are considered as background ones and other pixels as foreground ones.
size	A numeric containing the size of the brush, in pixels.
shape	A character vector indicating the shape of the brush. Can be box, disc or diamond. Default is box.
step	a logical indicating if the brush is binary. Default is TRUE.
iter	Deprecated argument.

Details

erode applies the mask positioning its centre over every background pixel (0), every pixel which is not covered by the mask is reset to foreground (1). In this way image features grow in size.

dilate applies the mask positioning its centre over every foreground pixel (!=0), every pixel which is not covered by the mask is reset to background (0). In this way image features seem shrink in size.

opening is an erosion followed by a dilation and closing is a dilation followed by an erosion.

makeBrush generates brushes of various sizes and shapes that can be used as structuring elements.

Value

dilate, erode, opening and closing return the transformed Image object or array, after the corresponding morphological operation.

makeBrush generates a 2D matrix containing the desired brush.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006

Examples

```
x = readImage(system.file("images", "shapes.png", package="EBImage"))
if (interactive()) display(x)
kern = makeBrush(5, shape='diamond')
if (interactive()) display(kern, title='Structuring element')
if (interactive()) display(erode(x, kern), title='Erosion of x')
if (interactive()) display(dilate(x, kern), title='Dilatation of x')

## makeBrush
x = makeBrush(100, shape='diamond')
if (interactive()) display(x, title="makeBrush(100, shape='diamond')")
x = makeBrush(100, shape='disc', step=FALSE)
if (interactive()) display(x, title="makeBrush(100, shape='disc', step=FALSE)")
```

normalize *Intensity values linear scaling*

Description

Linearly scale the intensity values of an image to a specified range.

Usage

```
normalize(x, separate=TRUE, ft=c(0,1))
```

Arguments

x	An Image object or an array.
separate	If TRUE, normalizes each frame separately.
ft	A numeric vector of 2 values, target minimum and maximum intensity values after normalization.

Value

An Image object or an array, containing the transformed version of x.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

Examples

```
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
y = bwlabel(x)
if (interactive()) display(x, title='Original')

print(range(y))
y = normalize(y)
print(range(y))

if (interactive()) display(y, title='Segmented')
```

ocontour *Oriented contours*

Description

Computes the oriented contour of objects.

Usage

```
ocontour(x)
```

Arguments

x	An Image object or an array, containing objects. Only integer values are considered. Pixels of value 0 constitute the background. Each object is a set of pixels with the same unique integer value. Objets are assumed connected.

Value

A list of matrices, containing the coordinates of object oriented contours.

Author(s)

Gregoire Pau, <gpau@ebi.ac.uk>, 2008

Examples

```
x = readImage(system.file("images", "shapes.png", package="EBImage"))
x = x[1:120,50:120]
if(interactive()) display(x)
oc = ocontour(x)
plot(oc[[1]], type='l')
points(oc[[1]], col=2)
```

---

paintObjects *Marks objects in images*

Description

This function marks objects in images.

Usage

```
paintObjects(x, tgt, opac=c(1, 1), col=c('red', NA))
```

Arguments

x	An Image object in Grayscale color mode or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
tgt	An Image object or an array, containing the intensity values of the objects.
opac	A numeric vector of two opacity values for drawing object boundaries and object bodies. Opacity ranges from 0 to 1, with 0 being fully transparent and 1 fully opaque.
col	A character vector of two R colors for drawing object boundaries and object bodies. By default, object boundaries are painted in red while object bodies are not painted.

Value

An Image object or an array, containing the painted version of tgt.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

See Also

bwlabel, watershed, link{getFeatures}

Examples

```
## load images
nuc = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
cel = readImage(system.file('images', 'cells.tif', package='EBImage'))
img = rgbImage(green=cel, blue=nuc)
if (interactive()) display(img, title='Cells')

## segment nuclei
nmask = thresh(nuc, 10, 10, 0.05)
nmask = opening(nmask, makeBrush(5, shape='disc'))
nmask = fillHull(nmask)
nmask = bwlabel(nmask)
if (interactive()) display(normalize(nmask), title='Cell nuclei mask')

## segment cells, using propagate and nuclei as 'seeds'
ctmask = opening(cel>0.1, makeBrush(5, shape='disc'))
cmask = propagate(cel, nmask, ctmask)
if (interactive()) display(normalize(cmask), title='Cell mask')

## using paintObjects to highlight objects
res = paintObjects(cmask, img, col='#ff00ff')
res = paintObjects(nmask, res, col='#ffff00')
if (interactive()) display(res, title='Segmented cells')
```

---

propagate *Voronoi-based segmentation on image manifolds*

Description

Find boundaries between adjacent regions in an image, where seeds have been already identified in the individual regions to be segmented. The method finds the Voronoi region of each seed on a manifold with a metric controlled by local image properties. The method is motivated by the problem of finding the borders of cells in microscopy images, given a labelling of the nuclei in the images.

Algorithm and implementation are from Jones et al. [1].

Usage

```
propagate(x, seeds, mask=NULL, lambda=1e-4, ext, seed.centers)
```

Arguments

x	An Image object or an array, containing the image to segment.
seeds	An Image object or an array, containing the seeding objects of the already identified regions.
mask	An optional Image object or an array, containing the binary image mask of the regions that can be segmented. If missing, the whole image is segmented.

`lambda`	A numeric value. The regularisation parameter used in the metric, determining the trade-off between the Euclidian distance in the image plane and the contribution of the gradient of `x`. See details.
`ext`	Deprecated.
`seed.centers`	Deprecated.

Details

The method operates by computing a discretized approximation of the Voronoi regions for given seed points on a Riemann manifold with a metric controlled by local image features.

Under this metric, the infinitesimal distance d between points v and v+dv is defined by:

```
d^2 = ( (t(dv)*g)^2 + lambda*t(dv)*dv )/(lambda + 1)
```

, where g is the gradient of image `x` at point v.

`lambda` controls the weight of the Euclidian distance term. When `lambda` tends to infinity, d tends to the Euclidian distance. When `lambda` tends to 0, d tends to the intensity gradient of the image.

The gradient is computed on a neighborhood of 3x3 pixels.

Segmentation of the Voronoi regions in the vicinity of flat areas (having a null gradient) with small values of `lambda` can suffer from artefacts coming from the metric approximation.

Value

An `Image` object or an array, containing the labelled objects.

License

The implementation is based on CellProfiler C++ source code [2, 3]. An LGPL license was granted by Thouis Jones to use this part of CellProfiler's code for the `propagate` function.

Author(s)

The original CellProfiler code is from Anne Carpenter <carpenter@wi.mit.edu>, Thouis Jones <thouis@csail.mit.edu>, In Han Kang <inthek@mit.edu>. Responsible for this implementation: Greg Pau.

References

[1] T. Jones, A. Carpenter and P. Golland, "Voronoi-Based Segmentation of Cells on Image Manifolds", CVBIA05 (535-543), 2005

[2] A. Carpenter, T.R. Jones, M.R. Lamprecht, C. Clarke, I.H. Kang, O. Friman, D. Guertin, J.H. Chang, R.A. Lindquist, J. Moffat, P. Golland and D.M. Sabatini, "CellProfiler: image analysis software for identifying and quantifying cell phenotypes", Genome Biology 2006, 7:R100

[3] CellProfiler: http://www.cellprofiler.org

See Also

`bwlabel`, `watershed`

Examples

```
## a paraboloid mountain in a plane
n = 400
x = (n/4)^2 - matrix(
       (rep(1:n, times=n) - n/2)^2 + (rep(1:n, each=n) - n/2)^2,
       nrow=n, ncol=n)
x = normalize(x)

## 4 seeds
seeds = array(0, dim=c(n,n))
seeds[51:55, 301:305] = 1
seeds[301:305, 101:105] = 2
seeds[201:205, 141:145] = 3
seeds[331:335, 351:355] = 4

lambda = 10^seq(-8, -1, by=1)
segmented = Image(dim=c(dim(x), length(lambda)))

for(i in seq(along=lambda)) {
  prop = propagate(x, seeds, lambda=lambda[i])
  prop = prop/max(prop)
  segmented[,,i] = prop
}

if(interactive()){
  display(x, title='Image')
  display(seeds/max(seeds), title='Seeds')
  display(segmented, title="Voronoi regions")
}
```

---

rmObjects *Object removal and reindexation*

Description

The `rmObjects` functions deletes objects from an image by setting their pixel intensity values to 0. `reenumerate` re-enumerates all objects in an image from 0 (background) to the actual number of objects.

Usage

```
rmObjects(x, index)

reenumerate(x)
```

Arguments

`x`	An `Image` object in `Grayscale` color mode or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
`index`	A numeric vector (or a list of vectors if `x` contains multiple frames) containing the indexes of objects to remove in the frame.

Value

An `Image` object or an array, containing the new objects.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

See Also

`bwlabel`, `watershed`

Examples

```
## make objects
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
y = bwlabel(x)
if (interactive()) display(normalize(y), title='Objects')

## remove and reenumerate
y = rmObjects(y, 5)
if (interactive()) display(normalize(y), title='Removal')
y = reenumerate(y)
if (interactive()) display(normalize(y), title='Reenumerated')
```

`resize` *Spatial linear transformations*

Description

Rotates, mirrors and resizes images.

Usage

```
flip(x)
flop(x)
resize(x, w, h, blur=1, filter="Lanczos")
rotate(x, angle=90)
```

Arguments

`x`	An `Image` object or an array.
`w, h`	Width and height of a new image. One of these arguments can be missing to enable proportional resizing.
`blur`	The blur factor, where 1 (`TRUE`) is blurry, 0 (`FALSE`) is sharp.
`filter`	Interpolating sampling filter.
`angle`	Image rotation angle in degrees.

Details

`flip` transforms `x` in its vertical mirror image by reflecting the pixels around the central x-axis.

`flop` transforms `x` in its horizontal mirror image by reflecting the pixels around the central y-axis.

`resize` scales the image to the desired dimensions using the supplied interpolating filter. Available filters are: `Point`, `Box`, `Triangle`, `Hermite`, `Hanning`, `Hamming`, `Blackman`, `Gaussian`, `Quadratic`, `Cubic`, `Catrom`, `Mitchell`, `Lanczos`, `Bessel` and `Sinc`. The filter `Box` performs a nearest-neighbor interpolation and is fast but introduces considerable aliasing. The filter `Triangle` performs a bilinear interpolation and is a good trade-off between speed adn aliasing. Cubic interpolation with the filter `Cubic` is also a good trade-off. High-quality and slower interpolation is achieved with the `Lanczos` filter. The algorithm used by this ImageMagick function is not well defined.

`rotate` rotates the image counter-clockwise with the specified angle. Rotated images are usually larger than the originals and have empty triangular corners filled in black. The algorithm used by this ImageMagick function is not well defined.

Value

An `Image` object or an array, containing the transformed version of `x`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

References

ImageMagick: http://www.imagemagick.org.

See Also

`translate`

Examples

```
x = readImage(system.file("images", "lena.gif", package="EBImage"))
if (interactive()) display(x)

y = flip(x)
if (interactive()) display(y, title='flip(x)')

y = flop(x)
if (interactive()) display(y, title='flop(x)')

y = resize(x, 128)
if (interactive()) display(y, title='resize(x, 128)')

y = rotate(x, 30)
if (interactive()) display(y, title='rotate(x, 30)')
```

`stackObjects` *Places detected objects into an image stack*

Description

Places detected objects into an image stack.

Usage

```
stackObjects(x, ref, index, combine=TRUE, rotate, bg.col='black', ext, centerb
```

Arguments

`x`	An `Image` object or an array containing object masks. Object masks are sets of pixels with the same unique integer value.
`ref`	An `Image` object or an array, containing the intensity values of the objects.
`combine`	If `x` contains multiple images, specifies if the resulting list of image stacks with individual objects should be combined using `combine` into a single image stack.
`bg.col`	Background pixel color.
`ext`	A numeric controlling the size of the output simage. If missing, `ext` is estimated from data. See details.
`index, rotate, centerby, rotateby`	Deprecated.

Details

`stackObjects` creates a set of `nbobj` images of size (`2*ext+1`, `2*ext+1`), where `nbobj` is the number of objects in `x`, and places each object of `x` in this set.

If not specified, `ext` is estimated using the 95% quantile of 2*sqrt(`g.l1`), where `g.l1` is the semi-major axis descriptor extracted from `hullFeatures`, taken over all the objects of the image `x`.

Value

An `Image` object containing the stacked objects contained in `x`. If `x` contains multiple images and if `combine` is `TRUE`, `stackObjects` returns a list of `Image` objects.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

See Also

`combine`, `tile`, `hullFeatures`

Examples

```
## simple example
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
y = bwlabel(x)
if (interactive()) display(normalize(y), title='Objects')
z = stackObjects(y, normalize(y))
if (interactive()) display(z, title='Stacked objects')

## load images
nuc = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
cel = readImage(system.file('images', 'cells.tif', package='EBImage'))
img = rgbImage(green=cel, blue=nuc)
if (interactive()) display(img, title='Cells')

## segment nuclei
nmask = thresh(nuc, 10, 10, 0.05)
nmask = opening(nmask, makeBrush(5, shape='disc'))
nmask = fillHull(bwlabel(nmask))

## segment cells, using propagate and nuclei as 'seeds'
ctmask = opening(cel>0.1, makeBrush(5, shape='disc'))
cmask = propagate(cel, nmask, ctmask)

## using paintObjects to highlight objects
res = paintObjects(cmask, img, col='#ff00ff')
res = paintObjects(nmask, res, col='#ffff00')
if (interactive()) display(res, title='Segmented cells')

## stacked cells
st = stackObjects(cmask, img)
if (interactive()) display(st, title='Stacked objects')
```

---

thresh *Adaptive thresholding*

Description

Thresholds an image using a moving rectangular window.

Usage

```
thresh(x, w=5, h=5, offset=0.01)
```

Arguments

x	An Image object or an array.
w, h	Width and height of the moving rectangular window.
offset	Thresholding offset from the averaged value.

Details

This function returns the binary image resulting from the comparison between an image and its filtered version with a rectangular window. It is equivalent of doing `{f = matrix(1, nc=2*w+1, nr=2*h+1) ; f=f/sum(f) ; x>(filter2(x, f)+offset)}` but slightly faster. The function `filter2` provides hence more flexbility than `thresh`.

Value

An `Image` object or an array, containing the transformed version of `x`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2005-2007

See Also

`filter2`

Examples

```
x = readImage(system.file('images', 'nuclei.tif', package='EBImage'))
if (interactive()) display(x)
y = thresh(x, 10, 10, 0.05)
if (interactive()) display(y)
```

`tile` *Tiling/untiling images*

Description

Given a sequence of frames, `tile` generates a single image with frames tiled. `untile` is the inverse function and divides an image into a sequence of images.

Usage

```
tile(x, nx=10, lwd=1, fg.col="#E4AF2B", bg.col="gray")
untile(x, nim, lwd=1)
```

Arguments

`x`	An `Image` object, an array or a list of these objects.
`nx`	The number of tiled images in a row.
`lwd`	The width of the grid lines between tiled images, can be 0.
`fg.col`	The color of the grid lines.
`bg.col`	The color of the background for extra tiles.
`nim`	A numeric vector of 2 elements for the number of images in both directions.

Details

After object segmentation, `tile` is a useful addition to `stackObjects` to have an overview of the segmented objects.

Value

An `Image` object or an array, containing the tiled/untiled version of `x`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2006-2007

See Also

`stackObjects`

Examples

```
## make a set of blurred Lenas
lena = readImage(system.file("images", "lena-color.png", package="EBImage"))
x = resize(lena, 128, 128)
xt = list()
for (t in seq(0.1, 5, len=9)) xt=c(xt, list(blur(x, s=t)))
xt = combine(xt)
if (interactive()) display(xt, title='Blurred Lenas')

## tile
xt = tile(xt, 3)
if (interactive()) display(xt, title='Tiled Lenas')

## untile
xu = untile(lena, c(3, 3))
if (interactive()) display(xu, title='Lena blocks')
```

`translate` *Image translation*

Description

Translates an image.

Usage

```
translate(x, v)
```

Arguments

`x`	An `Image` object or an array.
`v`	The translation vector or a matrix of translation vectors if `x` contains several images.

Details

Borders are repeated during translation.

Value

An `Image` object or an array, containing the translated version of `x`.

Author(s)

Gregoire Pau, <gpau@ebi.ac.uk>, 2008

See Also

`resize`, `rotate`

Examples

```
x = readImage(system.file("images", "lena-color.png", package="EBImage"))
y = translate(x, c(20,20))
if (interactive()) {
  display(x, title='Lena')
  display(y, title='Translated lena')
}

## gradient
y = translate(x, c(1,1))
if (interactive()) display(0.5+4*(y-x), title='NE gradient')
```

`watershed` *Watershed transformation and watershed based object detection*

Description

Watershed transformation and watershed based object detection.

Usage

```
watershed(x, tolerance=1, ext=1)
```

Arguments

`x`	An `Image` object or an array.
`tolerance`	The minimum height of the object in the units of image intensity between its highest point (seed) and the point where it contacts another object (checked for every contact pixel). If the height is smaller than the tolerance, the object will be combined with one of its neighbors, which is the highest. Tolerance should be chosen according to the range of `x`. Default value is 1, which is a reasonable value if `x` comes from `distmap`.
`ext`	Radius of the neighborhood in pixels for the detection of neighboring objects. Higher value smoothes out small objects.

Details

The algorithm identifies and separates objects that stand out of the background (zero). After the water fill, the source image is flipped upside down and the resulting valleys (values with higher intensities) are filled in first until another object or background is met. The deepest valleys (pixels with highest intensity) become indexed first, starting from 1.

The function `bwlabel` is a simpler, faster alternative to segment connected objects from binary images.

Value

An `Grayscale Image` object or an array, containing the labelled version of `x`.

Author(s)

Oleg Sklyar, <osklyar@ebi.ac.uk>, 2007

See Also

`bwlabel`, `propagate`

Examples

```
x = readImage(system.file('images', 'shapes.png', package='EBImage'))
x = x[110:512,1:130]
if (interactive()) display(x, title='Binary')
y = distmap(x)
if (interactive()) display(normalize(y), title='Distance map')
w = watershed(y)
if (interactive()) display(normalize(w), title='Watershed')
```

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