

# EImage

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---

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

<code>x</code>	An Image object, an array, or a list of Image objects and arrays.
<code>...</code>	Image objects or arrays.
<code>along</code>	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**

<code>x</code>	An Image object or an array.
<code>useGTK</code>	A logical of length 1. See details.
<code>title</code>	Window title.
<code>no.GTK, main, colorize</code>	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**

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

**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

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

### Authors

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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 <code>fft</code> transformation of the distance profile giving the frequencies of angular changes in shape.
scale	A logical value. If TRUE, the resulting profile is scaled by the effective radius (calculated as part of <code>link{hull.features}</code> ) making the profile scale invariant.
rotate	A logical value. If TRUE, the resulting profile is shifted by the object's rotation angle (calculated from the <code>moments</code> on the <code>ref</code> 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`:  $2\pi/1$  frequency component of the distance profile.
- `e.fPi`:  $2\pi/2$  frequency component of the distance profile.
- `e.f2Pi3`:  $2\pi/3$  frequency component of the distance profile.
- `e.fPi2`:  $2\pi/4$  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:**  $\sum_{i=2}^{2*nc} i * P_{x+y}(i)$ .

**h.sva Sum variance:**  $\sum_{i=2}^{2*nc} (i - sen)^2 * P_{x+y}(i)$ .

**h.sen Sum entropy:**  $-\sum_{i=2}^{2*nc} P_{x+y}(i) * \log(p(i, j))$ .

`h.ent` Entropy:  $-\sum_{i=1}^{nc} \sum_{j=1}^{nc} p(i, j) * \log(p(i, j))$ .  
`h.dva` Difference variance:  $\sum_{i=0}^{nc-1} (i^2) * P_{x-y}(i)$ .  
`h.den` Difference entropy:  $\sum_{i=0}^{nc-1} P_{x-y}(i) * \log(P_{x-y}(i, j))$ .  
`h.f12` Measure of correlation:  $\text{abs}(\text{ent} - \text{HXY1}) / \text{HX}$ .  
`h.f13` Measure of correlation:  $\text{sqrt}(1 - \exp(2 * (\text{ent} - \text{HXY2})))$ .

where:

`p` is the GLCM matrix.

`Px(i)` Marginal frequency. Defined by  $P_x(i) = \sum_{j=1}^{nc} p(i, j)$ .

`Py(j)` Marginal frequency. Defined by  $P_y(j) = \sum_{i=1}^{nc} p(i, j)$ .

`mux`, `muy` Means of `Px` and `Py`.

`sigmax`, `sigmay` Standard deviations of `Px` and `Py`.

`Px+y` Probability of the co-occurrence matrix coordinates sums to `x+y`. Defined by  $P_{x+y}(k) = \sum_{i=1}^{nc} \sum_{j=1}^{nc} p(i, j), i + j = k$  and  $k = 2, 3, \dots, 2*nc$ .

`Px-y` Probability of the absolute value of the difference between co-occurrence matrix coordinates being equal to `x-y`. Defined by  $P_{x-y}(k) = \sum_{i=1}^{nc} \sum_{j=1}^{nc} p(i, j), \text{abs}(i - j) = k$  and  $k = 2, 3, \dots, 2*nc$ .

`HXY1`  $-\sum_{i=1}^{nc} \sum_{j=1}^{nc} p(i, j) * \log(P_x(i), P_y(j))$ .

`HXY2`  $-\sum_{i=1}^{nc} \sum_{j=1}^{nc} P_x(i) * P_y(j) * \log(P_x(i), P_y(j))$ .

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](mailto:msmith@ebi.ac.uk)); Oleg Sklyar, ([osklyar@ebi.ac.uk](mailto: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 eigenvalue 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**

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

**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 object. See [Definitions](#) for details on features.

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

`rmoments` returns Hu's translation/rotation/scale 7 invariant moments `m.lk` 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:  $m_{pq} = \sum_{i,j \text{ st. } x_{ij}=k} i^p * j^q * ref_{ij}$ .

Central moments  $mu_{pq}$  are defined for the  $k$ -th object in `x` by:  $mu_{pq} = \sum_{i,j \text{ st. } x_{ij}=k} (i - m_10/m_00)^p * (j - m_01/m_00)^q * ref_{ij}$ . 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` =  $\sum_{i,j \text{ st. } x_{ij}=k} 1$
- `m.int` =  $m_00$
- `m.x` =  $m_10/m_00$
- `m.y` =  $m_01/m_00$
- `m.n20` =  $nu_20$
- `m.n11` =  $nu_11$
- `m.n02` =  $nu_02$
- `m.theta` =  $0.5 * \text{atan}(2 * mu_11 / (mu_20 - mu_02))$
- `m.l1` = largest eigenvalue of the covariance matrix  $[mu_20, mu_11 ; mu_11, mu_02]/m_00$
- `m.l2` = smallest eigenvalue of the covariance matrix
- `m.ecc` =  $\text{sqrt}(1 - m.l2/m.l1)$
- `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.
- $2*\text{sqrt}(m.l1)$  and  $2*\text{sqrt}(m.l2)$  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](mailto: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](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:

$$z.\{nl\} = (n+1) / \pi * \text{abs}(\text{sum}_{x,y}(V*nl(x,y) * i(x,y)) ),$$

where  $0 \leq l \leq n$ ,  $n - l$  is even and  $i(x,y)$  is the intensity of the reference image at the coordinates  $(x,y)$  that fall within 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  $j = \text{sqrt}(-1)$ ,  $\theta = \text{atan2}(y,x)$ , and

$$Qnl(x,y) = \sum_{m=0}^{(n-1)/2} ((-1)^m * (n-m)! * r^{(n-2*m)}) / (m! * ((n-2*m+1)/2)! * ((n-2*m-1)/2)!), \text{ where } r = \text{sqrt}(x^2+y^2).$$

## 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](http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/SHUTLER3/node11.html)

## See Also

[getFeatures](#)

## Examples

```
example(getFeatures)
```

---

fillHull	<i>Fill holes in objects</i>
----------	------------------------------

---

**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

<code>x</code>	An Image object or an array.
<code>filter</code>	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 frames, 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](mailto: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	<i>Extract feature extraction from image objects</i>
-------------	--

---

### 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 <a href="#">zernikeMoments</a> . Integer value defining the degree of the Zernike polynomials, which in turn defines the number of features calculated. Defaults to 12.
R	Passed to <a href="#">zernikeMoments</a> . Defines the radius of the circle around an object centre from which the features are calculated. See details. Defaults to 30.
nc	Passed to <a href="#">haralickFeatures</a> . 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 `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**

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

**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 <a href="#">Image</a> 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](mailto: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

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

<code>x</code>	An Image object or an array.
<code>separate</code>	If TRUE, normalizes each frame separately.
<code>ft</code>	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. Objects 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	<i>Marks objects in images</i>
--------------	--------------------------------

---

### 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](mailto: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

<code>x</code>	An Image object or an array, containing the image to segment.
<code>seeds</code>	An Image object or an array, containing the seeding objects of the already identified regions.
<code>mask</code>	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.
<code>lambda</code>	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 <code>x</code> . See details.
<code>ext</code>	Deprecated.
<code>seed.centers</code>	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.

To avoid to rely too much on single noisy pixels, 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)

Original CellProfiler code: Anne Carpenter <carpenter@wi.mit.edu>, Thouis Jones <thouis@csail.mit.edu>, In Han Kang <inthek@mit.edu>.

Port for this package: Oleg Sklyar, Gregoire Pau, Wolfgang Huber

### 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

<code>x</code>	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.
<code>index</code>	A numeric vector (or a list of vectors if <code>x</code> 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 and 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, centerby)
```

**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 `nboobj` images of size  $(2*ext+1, 2*ext+1)$ , where `nboobj` 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  $2*\sqrt{g.11}$ , where `g.11` 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](mailto: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	<i>Adaptive thresholding</i>
--------	------------------------------

---

### 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 flexibility 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	<i>Tiling/untiling images</i>
------	-------------------------------

---

### 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

<code>x</code>	An Image object, an array or a list of these objects.
<code>nx</code>	The number of tiled images in a row.
<code>lwd</code>	The width of the grid lines between tiled images, can be 0.
<code>fg.col</code>	The color of the grid lines.
<code>bg.col</code>	The color of the background for extra tiles.
<code>nim</code>	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](mailto: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')
```

**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 <code>distmap</code> .
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](mailto: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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