

# *RedCV Open Source Computer Vision Library*



## **What is RedCV**

RedCV means Red Language Open Source Computer Vision Library. It is a collection of Red functions and routines that give access to many popular Image Processing algorithms.

## **The key features**

RedCV provides cross-platform high level API that includes many functions. RedCV has no strict dependencies on external libraries. RedCV is free for both non-commercial and commercial use.

## **Who created it**

The list of authors and major contributors:

François Jouen for the library development.

Thanks to Nénad Rakocevic and Qingtian Xie for developing Red and their constant help.

Thanks to Didier Cadieu for samples optimization.

Thanks to Bruno Anselme for ZLib binding.

Thanks to Fyodor Shchukin for illustration.

## **Where to get RedCV**

Go <https://github.com/lhci/redCV>.

# *RedCV Reference Manual*

- Using RedCV library
- Basic structures
- Images and matrices basic operators
- Image and matrix utilities
- Format conversion
- Color and color space conversion
- Arithmetic operators
- Logic operators
- Statistics and image features extraction
- Geometrical transformations
- Distances
- Dynamic Time Warping
- Image enhancement
- Thresholding
- Spatial Filtering
- Fast Edge Detection
- Lines detection
- Shapes detection
- Mathematical morphology
- GUI functions
- Random generator

# Using RedCV Library

Most of functions are calling Red/System routines for faster image rendering. All redCV routines can be directly called from a red program (not for newbies). For a more convenient access, Red/System routines are exported as red functions. All red routines are prefixed with underscore (e.g. \_rcvCopy). **Only red functions are documented.**

All includes to redCV libraries are declared in a single file (/libs/redcv.red). You just need including *redcv.red* file in your Red programs.

```
[  
#include %core/rcvCore.red ; Basic image creating and processing functions  
#include %highgui/rcvHighGui.red ; Fast Highgui functions  
#include %matrix/rcvMatrix.red ; Matrices functions  
#include %imgproc/rcvImgProc.red ; Image processing functions  
#include %math/rcvRandom.red ; Random laws for generating random images  
#include %math/rcvStats.red ; Statistical functions for images  
#include %math/rcvDistance.red ; Distance algorithm for detection in images  
#include %ZLib/rcvZLib.red ; ZLib compression algorithms  
#include %tiff/rcvTiff.red ; Tiff image reading and writing]
```

```
; all we need for computer vision with Red  
#include %../..libs/redcv.red ; for red functions
```

## Some lectures

Image Processing in C, by Dwayne Phillips. The first edition of Image Processing in C (Copyright

1994, ISBN 0-13-104548-2) was published by R & D Publications

1601 West 23rd Street, Suite 200

Lawrence, Kansas 66046-0127

Algorithms for Image Processing and Computer Vision (2011) by J.R. Parker, published by Wiley Publishing, Inc.

10475 Crosspoint Boulevard

Indianapolis, IN 46256

# Basic Structures

## Image

RedCV directly uses Red image! datatype. Loaded images by Red are in ARGB format (a tuple). Images are 8-bit and internally uses bytes [0..255] as a binary string. Images are 4-channels and actually Red can't create 1, 2 or 3-channels images. Similarly Red can't create 16-bit (0..65536) 32-bit or 64-bit (0.0..1.0) images.

Each pixel channel ARGB is represented by a byte! The byte! datatype's purpose is to represent unsigned integers in the 0-255 range. Many libraries use a byte pointer to access ARGB components of a pixel. Red proposes an optimized which uses an integer to store ARGB values in a single value. Since the memory size of an integer is 32 bits, is really easy to store 4 bytes (8-bit) value with an integer. Consequently, a int-ptr! will be used to access pixel value.

Now to access to ARGB values stored in the integer, Red applies right shift operator, both unsigned right shift: >>> and signed right shift: >>

a: pix1/value >>> 24	; byte 1 [0-255] Alpha (transparency) channel
r: pix1/value and 00FF0000h >> 16	; byte 2 [0-255] Red channel
g: pix1/value and FF00h >> 8	; byte 3 [0-255] Green channel
b: pix1/value and FFh	; byte 4 [0-255] Blue channel

To write back pixel values, Red call signed left shift: << operator

pixD/value: (a << 24) OR (r << 16) OR (g << 8) OR b

## Matrix

Matrix! Datatype is not yet implemented by Red. A 100 x 100 color image is nothing but an array of 100 x 100 x 3 (for each R, G, B color channel ) numbers. Usually, we like to think of 100 x 100 x 3 array as a 3D array, but you can think of it as a long 1D array consisting of 30,000 elements. This is why we use vector! Datatype to simulate matrices with Red. Matrices are 2-D with n lines \*m columns with only one value. Matrix element can be Char!, Integer! or Float!. RedCV uses integer 8, 16 or 32-bit matrices or 32 or 64-bit float matrices.

# Images and matrices basic operators

## rcvCreateImage

**Creates and returns empty (black) image**

rcvCreateImage: function [size [pair!]] return: [image!]

size : image size width and height as a pair

```
dst: rcvCreateImage 512x512
```

## rcvGetImageSize

**Returns Image Size as a pair!**

rcvGetImageSize: function [src [image!]] return: [pair!]]

## rcvGetImageFileSize

**Gets Image File Size as a pair!**

rcvGetImageFileSize: function [fileName [file!]] return: [pair!]]

## rcvCreateMat

**Creates 2D matrix**

rcvCreateMat: function [ type [word!] bitSize [integer!] mSize [pair!]] return: [vector!]]

type: name of accepted datatype: char! | integer! | float!

bitSize: 8 for char!, 8 | 16 | 32 for integer!, 32 | 64 for float!

mSize: matrix size as pair

```
msize: 128x128
mat1: rcvCreateMat 'integer! 8 msize
mat2: rcvCreateMat 'integer! 16 msize
mat3: rcvCreateMat 'integer! 32 msize
```

## rcvLengthMat

**Returns matrix length**

rcvLengthMat: function [mat [vector!]] return: [integer!]]

## rcvMakeRangeMat

**Creates an ordered matrix**

rcvMakeRangeMat: function [a [number!] b [number!] step [number!]] return: [vector!]]

```
rcvMakeRangeMat -5.0 5.0 0.25 -> [-5.0 -4.75 -4.5 -4.25 -4.0 -3.75 -3.5 -3.25 -3.0 -2.75 -2.5 -
2.25 -2.0 -1.75 -1.5 -1.25 -1.0 -0.75 -0.5 -0.25 0.0 0.25 0.5 0.75 1.0 1.25 1.5 1.75 2.0 2.25 2.5
2.75 3.0 3.25 3.5 3.75 4.0 4.25 4.5 4.75 5.0]
```

```
rcvMakeRangeMat 1 10 1 -> [1 2 3 4 5 6 7 8 9 10]
```

## rcvMakeIdenticalMat

**Creates a matrix with identical values**

```
rcvMakeIdenticalMat: func [type [word!] bitSize [integer!] vSize [integer!] value  
[number!] return: [vector!]]
```

```
v: rcvMakeIdenticalMat 'Integer! 32 10 1 -> [1 1 1 1 1 1 1 1 1 1]  
v: rcvMakeIdenticalMat 'Integer! 32 10 5 -> [5 5 5 5 5 5 5 5 5 5]  
v: rcvMakeIdenticalMat 'Float! 64 10 0.25 -> [ 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25  
0.25]
```

## rcvMakeBinaryMat

**Makes a binary matrix [0..1]**

```
rcvMakeBinaryMat: function [src [vector!]] dst: [vector!]
```

```
Source matrix is 16 or 32-bit matrix [0..255]
```

## rcvReleaseImage

**Releases image data**

```
rcvReleaseImage: function [src [image!]]  
src : image to remove
```

## rcvReleaseAllImages

**Delete all images**

```
rcvReleaseAllImages: function [list [block!]]
```

```
loaded images must be stored into a block! before releasing
```

## rcvReleaseMat

**Releases Matrix**

```
rcvReleaseMat: function [mat [vector!]]  
mat: matrix to be released
```

```
Release functions will be probably removed according to Red garbage collector  
development.
```

## rcvLoadImage

**Loads image from file**

```
rcvLoadImage: function [fileName [file!]] return: [image!] /grayscale  
filename: name of the file to load as a Red file datatype  
/grayscale: loads image as grayscale
```

```
tmp: request-file  
if not none? tmp [ img1: rcvLoadImage tmp img2: rcvLoadImage /grayscale]
```

## rcvLoadTiffImage

loads TIFF image

rcvLoadTiffImage: func [f [file!]]

f: name of the Tiff file to load

```
tmp: request-file
```

```
if not none? tmp [ rcvLoadTiffImage tmp]
```

**Attention:** you need to call rcvTiff2RedImage function in order to display the image  
canvas/image: rcvTiff2RedImage

**Uncompressed bilevel, grayscale, palette-color images and RGB with samples per pixel up to 4 are supported.**

Samples Per Pixel is usually 1 for bilevel, grayscale, and palette-color images.

Samples Per Pixel is usually 3 for RGB images

## rcvReadTiffImageData

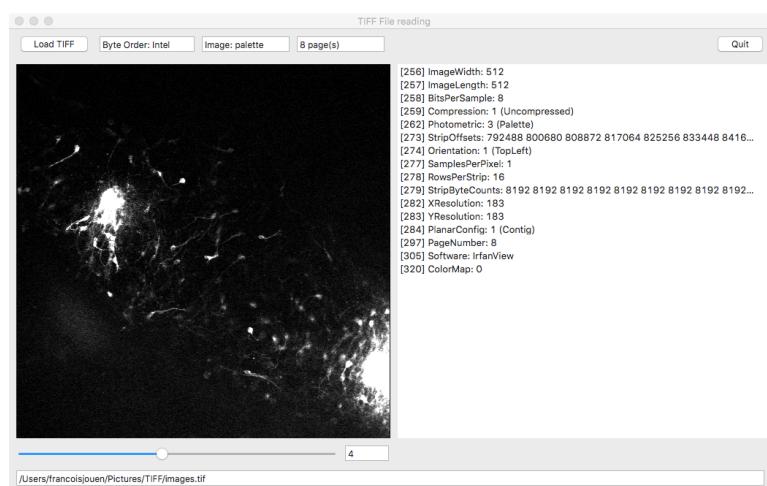
Reads multiple images included in TIFF File

rcvReadTiffImageData: func [page [integer!]]

page: number of image to access

Tiff files can include more than 1 image. You can use this function to access any image by its number.

**Attention:** you need to load first the tiff file before accessing image



## rcvLoadImageAsBinary

**Loads image from file and return image as binary**

rcvLoadImageAsBinary: function [fileName [file!]] return: [binary!] /alpha]

filename: name of the file to load as a Red file datatype

/ alpha: loads image as 4 channels image including alpha channel

## rcvSaveImage

**Save image to file**

rcvSaveImage: function [src [image!]] fileName [file!]]

src: image to save

filename: name of the file to save as a Red file datatype

Actually only png codec is supported for saving image. Will be improved in future by Red Team

## rcvSaveTiffImage

**Save red image as tiff**

rcvSaveTiffImage: func [anImage [image!] f [file!] mode [integer!]]

anImage: image to save

f: name of the file

mode : 1 little endian (Intel) / 2 big endiand (Motorola)

## rcvCloneImage

**Returns a copy of source image**

rcvCloneImage: function [src [image!]] return: [image!]]

src: image to be cloned

img: recCreateImage 512x512

hsv: rcvCloneImage img

## rcvCloneMat

**Returns a copy of source matrix**

rcvCloneMat: function [src [vector!]] return: [vector!]

src: matrice to be cloned

## rcvCopyImage

**Copies source image to destination image**

Source and destination image must have the same size!

rcvCopyImage: function [src [image!]] dst [image!]]

src: image to be copied

dst: destination

img: hsv : recCreateImage 512x512

hsv: rcvCopy img hsv

## rcvCopyMat

**Copy source matrix to destination matrix**

rcvCopyMat: function [src [vector!] dst [vector!]]

src: matrice to be copied

dst: destination matrix

## rcvZeroImage

**Sets all image pixels to 0**

rcvZeroImage: function [src [image!]]

src: image to clear

## rcvRandomImage

**Creates a random uniform color or pixel random image**

rcvRandomImage: function [size [pair!] value [tuple!] /uniform /alea return: [image!]]

size: size of image as pair!

Value: random value as tuple!

/uniform : random uniform color

/alea : random pixels

## rcvRandomMat

**Randomizes matrix**

rcvRandomMat: function [mat [vector!] value [integer!]]

mat: destination matrix

value: random value as integer!

```
mat1: rcvCreateMat 'integer! 8 msize
mat2: rcvCreateMat 'integer! 16 msize
mat3: rcvCreateMat 'integer! 32 msize
rcvRandomMat mat1 FFh
rcvRandomMat mat2 FFFFh
rcvRandomMat mat3 FFFFFFFh
```

## rcvColorImage

**Set image color**

function [src [image!] acolor [tuple!]]

src: image to color

acolor: required color as a tuple

## rcvColorMat

**Set matrix color**

rcvColorMat: function [mat [vector!] value [integer!]]

mat: destination matrix

value: color value as integer

```
mat1: rcvCreateMat 'integer! 8 msize  
rcvColorMat mat1 0
```

## rcvSortMat

**ascending sort of matrix**

rcvFlipMat: function [v [vector!] return: [vector!]] ]

## rcvFlipMat

flip matrix

rcvFlipMat: function [v [vector!] return: [vector!]]

## rcvCompressRGB

**Compresses rgb image values**

rcvCompressRGB: function [rgb [binary!] level [integer!] return: [binary!]]

rgb: rgb binary values of the image (image/rgb)

level: compression level for ZLib compression

[0: No compression

1: Best Speed

9: Best compression

-1: default compression]

## rcvDecompressRGB

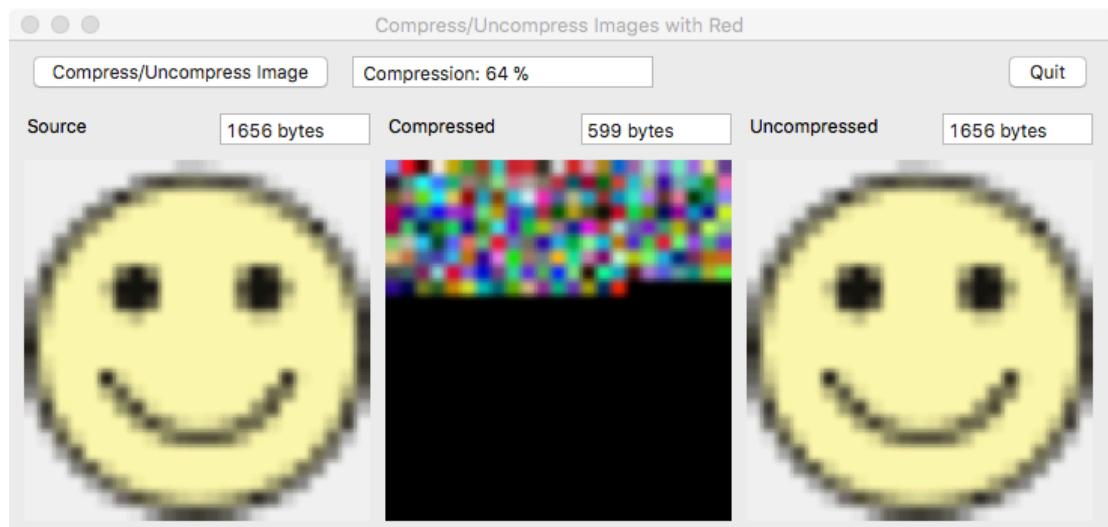
**Uncompresses rgb image values**

rcvDecompressRGB: function [rgb [binary!] bCount [integer!] return: [binary!]]

rgb: previously rgb compressed values

bCount: size of non-compressed rgb values

rgb: copy img/rgb	; image rgb values
clevel: 9	; zLib best compression
result: copy #{}{}	; for compressed data
result2: copy #{}{}	; for uncompressed data
n: length? rgb	; size of uncompressed data
result: rcvCompressRGB rgb clevel	; compress
result2: rcvDecompressRGB result n	; uncompress



# Image and matrix utilities

## rcvGetPixel

**Returns pixel value at xy coordinates**

rcvGetPixel: function [src [image!]] coordinate [pair!] return: [tuple!]]

src: image

coordinate: xy position in image as a pair

## rcvGetPixelAsInteger

**Returns pixel value at xy coordinates as integer**

rcvGetPixelAsInteger: function [src [image!]] coordinate [pair!] return: [integer!]]

src: image

coordinate: xy position in image as a pair

## rcvGetInt2D

**Returns integer matrix value at xy coordinates**

getInt2D: function [ src [vector!] mSize [pair] coordinate [pair!] return: [integer!]]

src: source matrix

coordinate: xy position of the element as a pair

msize: matrix size as pair!

## rcvGetReal2D

**Returns float matrix value at xy coordinates**

getInt2D: function [ src [vector!] mSize [pair] coordinate [pair!] return: [integer!]]

src: source matrix

msize: matrix size as pair!

coordinate: xy position of the element as a pair

## rcvSetPixel

**Sets pixel value at xy coordinates**

rcvSetPixel: function [src [image!]] coordinate [pair!] val [tuple!]]

src: image

coordinate: xy position in image as a pair

val : pixel value as a tuple

## rcvPokePixel

**Set pixel value at xy coordinates**

rcvPokePixel: function [src [image!]] coordinate [pair!] val [tuple!]]

## rcvSetInt2D

**Sets value in integer matrix**

setInt2D: function [ dst [vector!] mSize [pair] coordinate [pair!] val [integer!]]  
dst: destination matrix  
msize: matrix size as pair!  
coordinate: xy position of the element as a pair  
val: value as integer

## rcvSetReal2D

**Sets value in float matrix**

setInt2D: function [ dst [vector!] mSize [pair] coordinate [pair!] val [float!]]  
dst: destination matrix  
msize: matrix size as pair!  
coordinate: xy position of the element as a pair  
val: value as float

## rcvMatLeftPixel

**Gets coordinates of first left pixel**

rcvMatLeftPixel: function [mat [vector!] matSize [pair!] value [integer!] return: [pair!]  
mat: Integer matrix  
matSize: matrix size as pair  
value : pixel value (e.g. 1 or 255)

## rcvMatRightPixel

**Gets coordinates of first right pixel**

rcvMatRightPixel: function [mat [vector!] matSize [pair!] value [integer!] return: [pair!]  
mat: Integer matrix  
matSize: matrix size as pair  
value : pixel value (e.g. 1 or 255)

## rcvMatUpPixel

**Gets coordinates of first top pixel**

rcvMatRightPixel: function [mat [vector!] matSize [pair!] value [integer!] return: [pair!]  
mat: Integer matrix  
matSize: matrix size as pair  
value : pixel value (e.g. 1 or 255)

## rcvMatDownPixel

**Gets coordinates of first bottom pixel**

rcvMatRightPixel: function [mat [vector!] matSize [pair!] value [integer!] return: [pair!]  
mat: Integer matrix  
matSize: matrix size as pair  
value : pixel value (e.g. 1 or 255)

## rcvSetAlpha

**Sets image transparency**

rcvSetAlpha: function [src [image!] dst [image!] alpha [integer!]]

src: image remains unchanged and transparency is modified for destination image

alpha : transparency value [0..255]

sl: slider 256 [t: 255 - (to integer! sl/data \* 255) rcvSetAlpha img1 img2 t]

## rcvBlend

**Computes the alpha blending of two images**

rcvBlend: function [src1 [image!] src2 [image!] dst [image!] alpha [float!]]

src1: first image

src2: second image

dst: destination image

alpha: ratio of first image mixed with the second. Float value [0.0-1.0]

## rcvBlendMat

**Computes the alpha blending of two matrices**

rcvBlendMat: function [ mat1 [vector!] mat2 [vector!] dst [vector!] alpha [float!]]

mat1: first matrix

mat2: second matrix

dst: destination matrix

alpha: ratio of first matrix mixed with the second. Float value [0.0-1.0]

# Format conversion

## rcvImage2Mat

**Converts Red Image to 8-bit 2-D Matrix**

rcvImage2Mat: function [src [image!]] mat [vector!]]

src: image

mat: vector

Grayscale

## rcvMat2Image

**Converts 8, 16 or 32-bit integer Matrix to Red Image**

rcvMat2Image: function [mat [vector!]] dst [image!]]

mat: vector

dst: image

## rcvConvertMatScale

**Converts Matrix Scale to another bit size**

rcvConvertMatScale: function [src [vector!]] dst [vector!] srcScale [number!] dstScale [number!] /fast /normal]

src: vector

dst: vector

srcScale: source range e.g 255

dstScale : destination range e.g 65535

/normal : uses a general function

/fast: uses a faster routine

```
msize: 256x256
mat1: rcvCreateMat 'integer! 8 msize
mat2: rcvCreateMat 'integer! 16 msize
mat3: rcvCreateMat 'integer! 32 msize
rcvConvertMatScale/normal mat1 mat2 FFh FFFFh
rcvConvertMatScale/normal mat1 mat3 FFh FFFFFFFh
```

## rcvMatInt2Float

**Converts integer matrix to float [0..1] matrix**

rcvMatInt2Float: function [src [vector!]] dst [vector!] srcScale [float!]]

src: source matrix

dst: destination matrix

srcScale: source range as a float!

## rcvMatFloat2Int

**Converts float matrix to integer [0..255] matrix**

rcvMatFloat2Int: function [src [vector!]] dst [vector!]

src: source matrix

dst: destination matrix

## rcvSplit

**Separates source image in ARGB channels. Destination contains selected source channel.**

rcvSplit: function [src [image!]] dst [image!]/red /green /blue /alpha]

src: source image

dst: destination image

/red: red channel

/green: green channel

/blue: blue channel

/alpha: alpha channel

## rcvSplit2Mat

**Separates image channels to 4 8-bit matrices**

rcvSplit2Mat: function [src [image!]] mat0 [vector!] mat1 [vector!] mat2 [vector!] mat3 [vector!]]

src: image

mat0: image alpha channel

mat1: image red channel

mat2: image green channel

mat3: image blue channel

if source image is grayscale then mat1 = mat2 = mat3.

## rcvMerge2Image

**Merges 4 8-bit matrices to Red image**

rcvMerge2Image: function [ mat0 [vector!] mat1 [vector!] mat2 [vector!] mat3 [vector!] dst [image!]]

mat0: image alpha channel

mat1: image red channel

mat2: image green channel

mat3: image blue channel

dst: image

## rcvTiff2RedImage

**Converts TIFF image to Red image**

rcvTiff2RedImage: func [return: [image!]]

**Attention:** you need a loaded Tiff File. See rcvLoadTiffImage documentation.

# Color and color space conversion

## rcvInvert

**Destination image: inverted source image (Similar to NOT image)**

rcvInvert: function [source [image!] dst [image!]]

src: source image

dst: destination image

## rcv2BW

**Converts RGB image to black[0] and white [255]**

rcv2BW: function [src [image!] dst [image!]]

src: source image

dst: destination image

## rcv2WB

**Converts RGB image to white [255] and black[0]**

rcv2WB: function [src [image!] dst [image!]]

src: source image

dst: destination image

rcv2BW: background = 0

rcv2WB: background = 255

Internal threshold value equal to 128. For an accurate thresholding see rcv2BWFilter function.

## rcv2Gray

**Converts RGB image to Grayscale according to refinement**

rcv2Gray: function [ src [image!] dst [image!] /average /luminosity /lightness return: [image!]]

src: source image

dst: destination image

The average method simply averages the values:  $(R + G + B) / 3$ .

The lightness method averages the most prominent and least prominent colors:  $(\max(R, G, B) + \min(R, G, B)) / 2$ .

The luminosity method is a more sophisticated version of the average method. It also averages the values, but it forms a weighted average to account for human perception. The formula for luminosity is  $0.21 R + 0.72 G + 0.07 B$ .

## rcv2BGRA

### Converts RGBA to BGRA

rcv2BGRA: function [src [image!] dst [image!]]

src: source image

dst: destination image

## rcv2RGBA

### Converts BGRA to RGBA

rcv2RGBA: function [src [image!] dst [image!]]

src: source image

dst: destination image

## rcvRGB2HSV

### RBG color to HSV conversion

rcvRGB2HSV: function [src [image!] dst [image!]]

src: image

dst: image

## rcvBGR2HSV

### BGR color to HSV conversion

rcvBGR2HSV: function [src [image!] dst [image!]]

src: image

dst: image

The Hue/Saturation/Value model was created by A. R. Smith in 1978. The coordinate system is cylindrical. The hue value H runs from 0 to 360°. The saturation S is the degree of purity and is from 0 to 1. Purity is how much white is added to the color. S=1 makes the purest color (no white). Brightness V also ranges from 0 to 1, where 0 is the black. There is no transformation matrix for RGB or BGR to HSV conversion, but R, G and B are converted to floating-point format and scaled to fit 0..1 range.

## rcvRGB2HLS

### RBG color to HLS conversion

rcvRGB2HLS: function [src [image!] dst [image!]]

src: image

dst: image

## rcvBGR2HLS

### RBG color to HLS conversion

rcvBGR2HLS: function [src [image!] dst [image!]]

src: image

dst: image

Also a cylindrical coordinates system. There is no transformation matrix for RGB or BGR to HLS conversion, but R, G and B are converted to floating-point format and scaled to fit 0..1 range.

## rcvRGB2YCrCb

### RBG color to YCrCb conversion

rcvRGB2YCrCb: function [src [image!] dst [image!]]

src: image

dst: image

## rcvBGR2YCrCb

### BGR color to YCrCb conversion

rcvBGR2YCrCb: function [src [image!] dst [image!]]

src: image

dst: image

There is no transformation matrix.

$$Y \leftarrow 0.299 * R + 0.587 * G + 0.114 * B$$

$$Cr \leftarrow (R - Y) * 0.713 + \text{delta}$$

$$Cb \leftarrow (B - Y) * 0.564 + \text{delta}$$

## rcvRGB2XYZ

### RGB to CIE XYZ color conversion

rcvRGB2XYZ: function [src [image!] dst [image!]]

src: image

dst: image

## rcvBGR2XYZ

### BGR to CIE XYZ color conversion

rcvBGR2XYZ: function [src [image!] dst [image!]]

src: image

dst: image

To transform from XYZ to RGB the matrix transform used is :

$$[ X ] \quad [ 0.412453 \ 0.357580 \ 0.180423 ] \quad [ R ]$$

$$[ Y ] = [ 0.212671 \ 0.715160 \ 0.072169 ] * [ G ]$$

$$[ Z ] \quad [ 0.019334 \ 0.119193 \ 0.950227 ] \quad [ B ]$$

## rcvRGB2Lab

### RBG color to CIE L\*a\*b conversion

rcvRGB2Lab: function [src [image!] dst [image!]]

src: image

dst: image

## rcvRGB2Lab

### RBG color to CIE L\*a\*b conversion

rcvBGR2Lab: function [src [image!] dst [image!]]

src: image

dst: image

R, G and B are converted to floating-point format and scaled to fit 0..1 range. R, G and B are first converted to CIE XYZ before processing. On output  $0 \leq L \leq 100$ ,  $-127 \leq a \leq 127$ ,  $-127 \leq b \leq 127$ . The values are then converted to 8-bit images:  $L <- L * 255 / 100$ ,  $a <- a + 128$ ,  $b <- b + 128$ .

## rcvRGB2Luv

### RBG color to CIE L\*u\*v conversion

rcvRGB2Luv: function [src [image!] dst [image!]]

src: image

dst: image

## rcvRGB2Luv

### RBG color to CIE L\*u\*v conversion

rcvBGR2Luv: function [src [image!] dst [image!]]

src: image

dst: image

R, G and B are converted to floating-point format and scaled to fit 0..1 range. R, G and B are first converted to CIE XYZ before processing. On output  $0 \leq L \leq 100$ ,  $-134 \leq u \leq 220$ ,  $-140 \leq v \leq 122$ . The values are then converted to 8-bit images:  $L <- L * 255 / 100$ ,  $u <- (u + 134) * 255 / 354$ ,  $v <- (v + 140) * 255 / 256$ .

# Arithmetic operators

## rcvAdd

**dst: src1 + src2**

rcvAdd: function [src1 [image!]] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## rcvAddMat

**dst: src1 + src2**

rcvAddMat: function [src1 [vector!]] src2 [vector!] return: [vector!]]

src1: first matrix

src2: second matrix

## rcvAddLIP

**Destination image: image 1 + image 2 (Logarithmic Image Processing)**

rcvAddLIP : function [src1 [image!]] src2 [image!] dst [image!]

src1: image

src2: image

dst: image

Computes the addition of the two input images, according to the LIP model (Logarithmic Image Processing). The LIP image addition is defined as:

$$\text{dest}(x,y) = \text{src1}(x,y) + \text{src2}(x,y) - (\text{src1}(x,y) * \text{src2}(x,y)) / M$$

where M is the number of gray tones (256 for byte image)

## rcvSub

**dst: src1 - src2**

rcvSub: function [src1 [image!]] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## rcvSubMat

**dst: src1 - src2**

rcvSubMat: function [src1 [vector!]] src2 [vector!] return: [vector!]]

src1: first matrix

src2: second matrix

## rcvSubLIP

**Destination image: image 1 - image 2 (Logarithmic Image Processing)**

rcvSubLIP: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

Computes the difference of the two input images, according to the LIP model (Logarithmic Image Processing). The LIP image addition is defined as:

$$\text{dest}(x,y) = M^*(\text{src1}(x,y) - \text{src2}(x,y)) / (M - \text{src2}(x,y))$$

where M is the number of gray tones (256 for byte image)

## rcvMul

**dst: src1 \* src2**

rcvMul: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## rcvMulMat

**dst: src1 \* src2**

rcvMulMat: function [src1 [vector!] src2 [vector!] return: [vector!]]

src1: first matrix

src2: second matrix

## rcvDiv

**dst: src1 / src2**

rcvDiv: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## rcvDivMat

**dst: src1 / src2**

rcvDivMat: function [src1 [vector!] src2 [vector!] return: [vector!]]

src1: first matrix

src2: second matrix

## **rcvMod**

**dst: src1 // src2 (modulo)**

rcvMod: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## **rcvRem**

**dst: src1 % src2 (remainder)**

rcvRem: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## **rcvRemMat**

**dst: src1 % src2**

rcvRemMat: function [src1 [vector!] src2 [vector!] return: [vector!]]

src1: first matrix

src2: second matrix

## **rcvAbsDiff**

**dst: absolute difference src1 src2**

rcvAbsDiff: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## **rcvMIN**

**dst: minimum src1 src2**

rcvMIN: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## **rcvMAX**

**dst: maximum src1 src2**

rcvMax: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## **rcvLSH**

### **Left shift image by value**

rcvLSH: function [src [image!] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvRSH**

### **Right shift image by value**

rcvRSH: function [src [image!] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvPow**

### **dst: src ^integer! or Float! Value**

rcvPow: function [src [image!] dst [image!] val [number!]]

src: image

dst: image

val: integer or float

## **rcvSqr**

### **Image square root**

rcvSqr: function [src [image!] dst [image!] val [number!]]

src: image

dst: image

val: integer or float

## **rcvExp**

TBD requires float images

## **rcvLog**

TBD requires float images

## **rcvMeanImages**

### **dst: (src1 + src2) /2**

rcvMeanImages: function [src1 [image!] src2 [image!] dst [image!]]

src1: image

src2: image

dst: image

## rcvMeanMats

**Calculate mean values for 2 matrices**

rcvMeanMats: function [src1 [vector!]] src2 [vector!] return: [vector!]

src1: matrix 1

src2: matrix 2

## rcvAddS

**dst: src + integer! value**

rcvAddS: function [src [image!]] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## rcvAddSMat

**src + value**

rcvAddSMat: function [src [vector!]] value [integer!]]

src: matrix

value: integer

## rcvAddT

**dst: src + tuple! value**

rcvAddT: function [src [image!]] dst [image!] val [tuple!]]

## rcvSubS

**dst: src - integer! value**

rcvSubS: function [src [image!]] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## rcvSubSMat

**src - value**

rcvSubSMat: function [src [vector!]] value [integer!]]

src: matrix

value: integer

## rcvSubT

**dst: src - tuple! value**

rcvSubT: function [src [image!]] dst [image!] val [tuple!]]

## **rcvMulS**

**dst: src \* integer! value**

rcvMulS: function [src [image!]] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvMulSMat:**

**dst: src \* integer! value**

rcvMulSMat: function [src [vector!]] value [integer!]

src: matrix

val: integer

## **rcvMult**

**dst: src \* tuple! value**

rcvMult: function [src [image!]] dst [image!] val [tuple!]]

## **rcvDivS**

**dst: src / integer! value**

rcvDivS: function [src [image!]] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvDivSMat**

**src / value**

rcvDivSMat: function [src [vector!]] value [integer!]]

src: matrix

value: integer

## **rcvDivT**

**dst: src / tuple! value**

rcvDivT: function [src [image!]] dst [image!] val [tuple!]]

## **rcvModS**

**dst: src // integer! Value (modulo)**

rcvModS: function [src [image!]] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvModT**

**dst: src // tuple! Value (modulo)**

rcvModT: function [src [image!] dst [image!] val [tuple!]]

## **rcvRemS**

**dst: src % integer! Value (remainder)**

rcvRemS: function [src [image!] dst [image!] val [integer!]]

src: image

dst: image

val: integer

## **rcvRemT**

**dst: src % tuple! Value (remainder)**

rcvRemT: function [src [image!] dst [image!] val [tuple!]]

## **rcvRemSMat**

**src % value (remainder)**

rcvRemSMat: function [src [vector!] value [integer!]]

src: matrix

value: integer

# Logic operators

## rcvAND

**dst: src1 AND src2**

rcvAND: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 and src2

## rcvANDMat

**Returns source1 AND source2**

rcvAndMat: function [src1 [vector!]] src2 [vector!] return: [vector!]

src1: first matrice

src2: second matrice

## rcvOR

**dst: src1 OR src2**

rcvOR: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 or src2

## rcvORMat

**Returns source1 OR source2**

rcvORMat: function [src1 [vector!]] src2 [vector!] return: [vector!]

src1: first matrice

src2: second matrice

## rcvXOR

**dst: src1 XOR src2**

rcvXOR: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 xor src2

## rcvXORMat

**Returns source1 XOR source2**

rcvXORMat: function [src1 [vector!]] src2 [vector!] return: [vector!]

src1: first matrice

src2: second matrice

## rcvNAND

### dst: src1 NAND src2

rcvNAND: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 nand src2

## rcvNOR

### dst: src1 NOR src2

rcvNOR: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 nor src2

## rcvNXOR

### dst: src1 NXOR src2

rcvNXOR: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 nxor src2

## rcvNOT

### dst: src1 NOT src2

rcvNOT: function [src1 [image!]] src2 [image!] dst [image!]]

src1: first image

src2: second image

dst: src1 not src2

## rcvANDS

**Tuple value is use to create a colored image which is ANDed to source image. Result is copied to destination**

rcvANDS: function [src [image!]] dst [image!] value [tuple!]

src: source image

dst: image

value: tuple!

```
rcvANDS img1 dst 255.0.0.0; dst: add red color to img1
```

## rcvORS

**Tuple value is use to create a colored image which is ORed to source image. Result is copied to destination**

rcvORS: function [src [image!]] dst [image!] value [tuple!]  
src: source image  
dst: image  
value: tuple!

## rcvXORS

**Tuple value is use to create a colored image which is XORed to source image. Result is copied to destination**

rcvXORS: function [src [image!]] dst [image!] value [tuple!]  
src: source image  
dst: image  
value: tuple!

## rcvANDSMat

**And integer value to all element in source matrix**

rcvANDSMat: function [src [vector!]] value [integer!]  
src: matrice  
value: integer!

## rcvORSMat

**OR integer value to all element in source matrix**

rcvANDSMat: function [src [vector!]] value [integer!]  
src: matrice  
value: integer!

## rcvXORSMat

**XOR integer value to all element in source matrix**

rcvANDSMat: function [src [vector!]] value [integer!]  
src: matrice  
value: integer!

# Statistics and image features extraction

## rcvCountNonZero

**Returns number of non-zero values in image or matrix**

rcvCountNonZero: function [arr [image! vector!]] return: [integer!]]

arr: image or vector

## rcvSum

**Returns sum value of image or matrix as a block of rgb values**

rcvSum: function [arr [image! vector!]] return: [block!] /argb]

arr: image or vector

/argb: includes alpha channel

## rcvSumMat

**Returns matrix sum as a float value**

rcvSumMat: function [mat [vector!]] return: [float!]]

## rcvMean

**Returns mean value of image or matrix as a tuple of rgb values**

rcvMean: function [arr [image! vector!]] return: [tuple!] /argb]

arr: image or vector

/argb: includes alpha channel

## rcvMeanMat

**Returns matrix mean as float value**

rcvMeanMat: function [mat [vector!]] return: [float!]]

## rcvSTD

**Returns standard deviation value of image or matrix as a block of rgb values**

rcvSTD: function [arr [image! vector!]] return: [tuple!] /argb]

arr: image or vector

/argb: includes alpha channel

## rcvMedian

**Returns median value of image or matrix as a block of rgb values**

rcvMedian: function [arr [image! vector!]] return: [tuple!] /argb]

arr: image or vector

/argb: includes alpha channel

## **rcvProdMat**

**Return matrix product as a float value**

rcvProdMat: function [mat [vector!]] return: [float!]]

## **rcvMinValue**

**Returns minimal value of image or matrix as a block of rgb values**

rcvMinValue: function [arr [image! vector!]] return: [tuple!]]

arr: image or vector

## **rcvMaxValue**

**Returns maximum value of image or matrix as a block of rgb values**

rcvMaxValue: function [arr [image! vector!]] return: [tuple!]]

arr: image or vector

## **rcvMaxMat**

**Return maximum of matrix as a number**

rcvMaxMat: function [mat [vector!]] return: [number!]]

## **cvMinMat**

Return minimum of matrix as a number

rcvMinMat: function [mat [vector!]] return: [number!]]

## **rcvMinLoc**

**Finds global minimum location in array**

rcvMinLoc: function [arr [image! vector!]] arrSize [pair!] return: [pair!]]

arr: image or vector

arrSize: array size as pair

## **rcvMaxLoc**

**Finds global maximum location in array**

rcvMaxLoc: function [arr [image! vector!]] arrSize [pair!] return: [pair!]]

arr: image or vector

arrSize: array size as pair



## rcvHistogram

**Calculates array histogram**

rcvHistogram: function [arr [image! vector!]] return: [vector!] /red /green /blue]

arr: image or vector

/red: histogram for red channel

/green: histogram for green channel

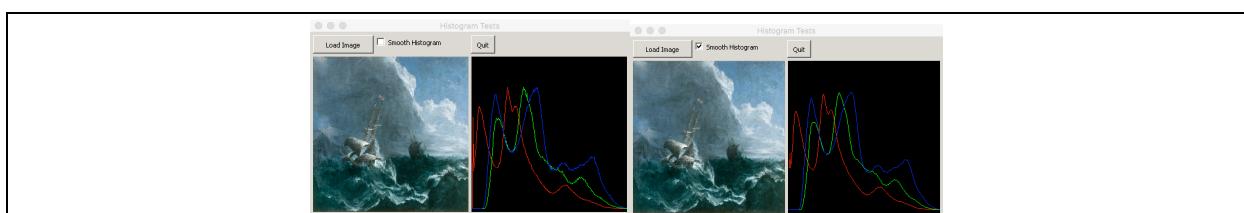
/blue: histogram for blue channel

## rcvSmoothHistogram

**This function smoothes the input histogram by a 3 points mean moving average**

rcvSmoothHistogram: function [arr [vector!]] return: [vector!]

arr: input histogram as vector!



## rcvRangedImage

**Gives range value in image as a tuple**

rcvRangedImage: function [source [image!]] return: [tuple!]

source: image

## rcvGetMatSpatialMoment

**Returns the spatial moment of the mat**

rcvGetMatSpatialMoment: function [

mat [vector!]

matSize [pair!]

p [float!]

```
    q [float!]
    return: [float!]
]
```

```
p - the order of the moment
q - the repetition of the moment
p: q: 0.0 -> moment order 0 -> form area
```

## rcvGetMatCentralMoment

**Returns the central moment of the mat**

```
rcvGetMatCentralMoment: function [
    mat [vector!]
    matSize [pair!]
    p      [float!]
    q      [float!]
    return: [float!]
]
```

## rcvGetNormalizedCentralMoment

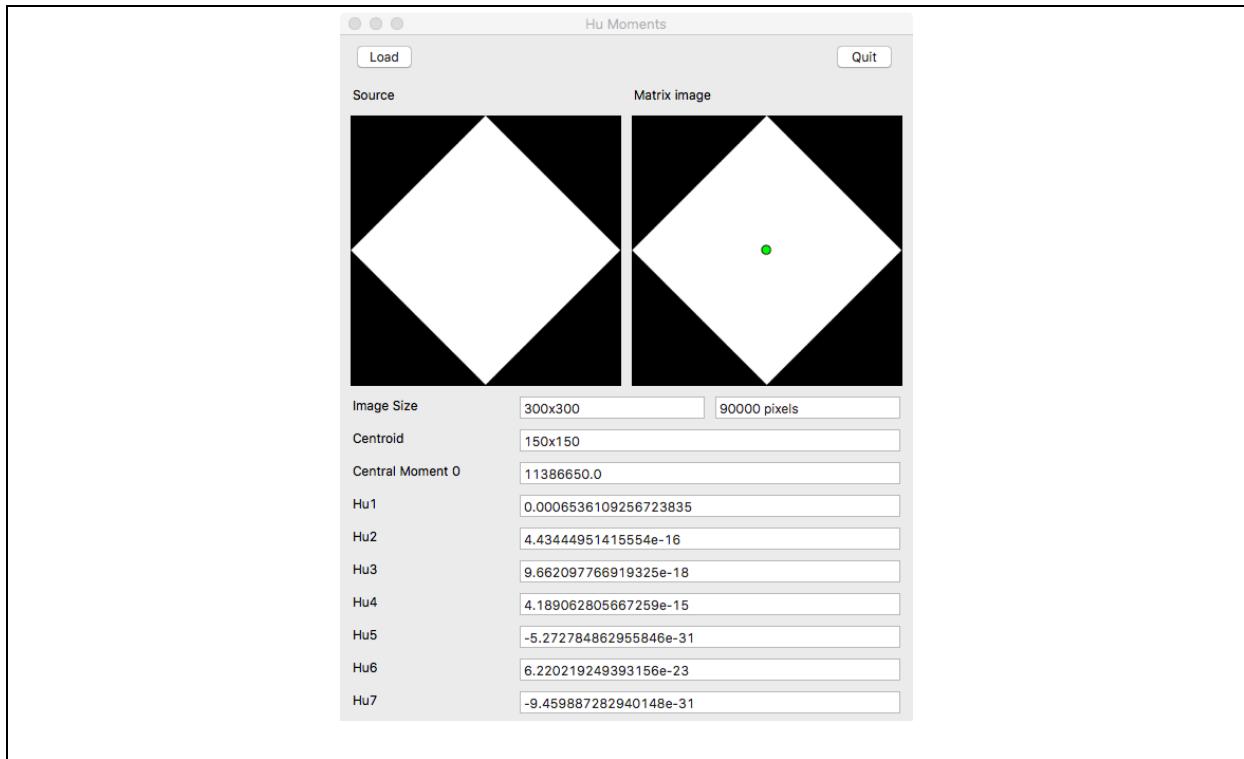
**Return the scale invariant moment of the image**

```
rcvGetNormalizedCentralMoment: function [
    mat [vector!]
    matSize [pair!]
    p      [float!]
    q      [float!]
    return: [float!]
]
```

## rcvGetMatHuMoments

**Returns Hu moments of the image**

```
rcvGetMatHuMoments: function [
    "Returns Hu moments of the image"
    mat [vector!]
    matSize [pair!]
    return: [block!]
]
```



Hu Moments are normally extracted from the outline of an object in an image. An **image moment** is a particular weighted average of the image pixels' intensities, or a function of such moments, usually chosen to have some attractive property.

## rcvSortImage

### Ascending image sorting

rcvSortImage: function [source [image!]] dst [image!]]

source: image

dst: image

## rcvIntegral

**Calculates integral images**

rcvIntegral: function [src [image!]] sum [image!] sqsum [image!]

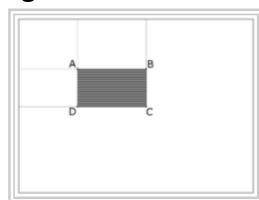
src: image or integer matrice

sum: image or integer matrice for summed area table

sqsum: image or integer matrice for square summed area table

mSize : image or integer matrice size as a pair!

Using these integral images, one may calculate sum, mean, standard deviation over arbitrary up-right rectangular region of the image in a constant time with only 4 points ABCD.



Using integral image, it is also possible to do variable-size image blurring, block correlation etc.

Integral image  $ii$  is defined according to :

$$ii(x, y) = \sum_{x' \leq x, y' \leq y} i(x', y')$$

## rcvQuickHull

**Finds the convex hull of a point set**

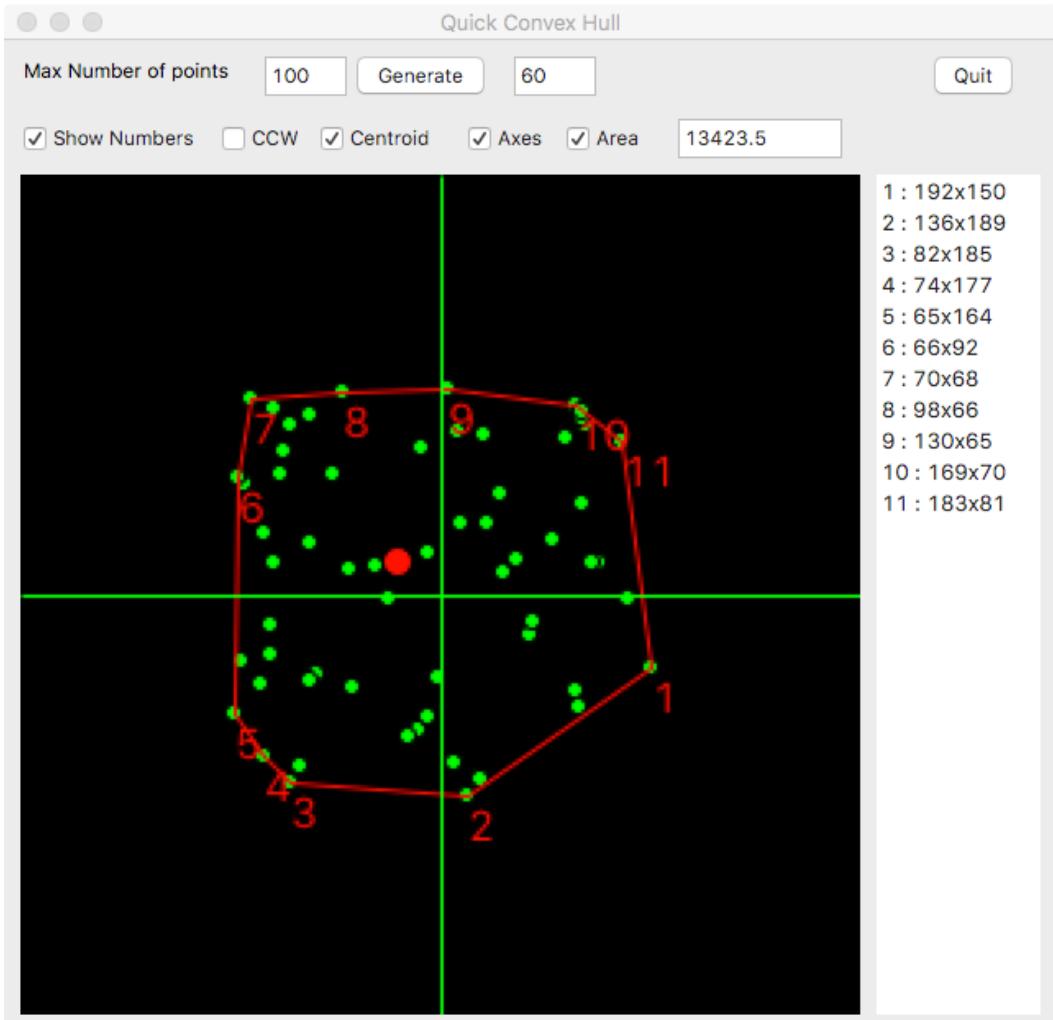
rcvQuickHull: function [points [block!]] return: [block!] /cw/ccw]

points: Input 2D point set as pair!

Returns output convex hull as a block of pair

/cw/ccw : Orientation flag. If cw, the output convex hull is oriented clockwise. Otherwise, it is oriented counter-clockwise. The assumed coordinate system has its X axis pointing to the right, and its Y axis pointing upwards.

The convex hull problem in geometry tries to find the smallest convex set containing the points.



There are many approaches for handling this problem, but for RedCV we focused on the *Quick Hull algorithm*, which is one of the easiest to implement and has a reasonable expected running time of  $O(n \log n)$ . A clear explanation of the algorithm can be found here: <http://www.ahristov.com/tutorial/geometry-games/convex-hull.html>. Thanks to Alexander Hristov for the original Java code.

## rcvContourArea

**Calculates the area of polygon generated by rcvQuickHull function**

rcvContourArea: function [hull [block!]] return: [float!] /signed]

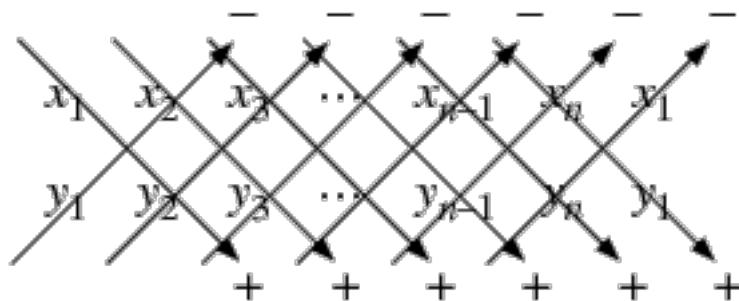
hull: list of coordinates (as pair!) generated by the rcvQuickHull function

Return: area as float!

If signed refinement is used returns the signed area

This function returns the (signed or not) area ( $A$ ) of a planar **non-self-intersecting** polygon with vertices  $(x_1, y_1), \dots, (x_n, y_n)$  according to the formula:

$$A = \frac{1}{2} (x_1 y_2 - x_2 y_1 + x_2 y_3 - x_3 y_2 + \dots + x_{n-1} y_n - x_n y_{n-1} + x_n y_1 - x_1 y_n),$$



See Weisstein, Eric W. "Polygon Area." From MathWorld--A Wolfram Web Resource.  
<http://mathworld.wolfram.com/PolygonArea.html>

# Geometrical transformations

## rcvFlip

**Left/Right, Up/Down or both directions image flip**

rcvFlip: function [src [image!]] dst [image!] /horizontal /vertical /both return: [image!]]

src: source image

dst: destination image

refinement for direction



## rcvResizeImage

**Resizes image and applies filter for Gaussian pyramidal up or downsizing if required**

rcvResizeImage: function [src [image!]] iSize [pair!]/Gaussian return: [pair!]]

src: destination image

canvas: Red base face containing the image

iSize: New size of the image as pair

/Gaussian: applies a 5x5 kernel Gaussian filter on image

```
img1: rcvLoadImage %..../..../images/lena.jpg
```

```
dst: rcvCreateImage img1/size
```

```
iSize: 256x256
```

```
canvas: base iSize dst
```

```
nSize: 512x512
```

```
rcvResizeImage dst nSize
```

```
canvas/size: nSize
```

```
dst: to-image canvas
```

## rcvScaleImage

Sets the scale factors: Returns a Draw block

rcvScaleImage: function [factor [float!] return: [block!]]

factor: scale factor as float! Default value : 1.0 original size

This function uses Draw Dialect and you have to add the image instance to the draw block.

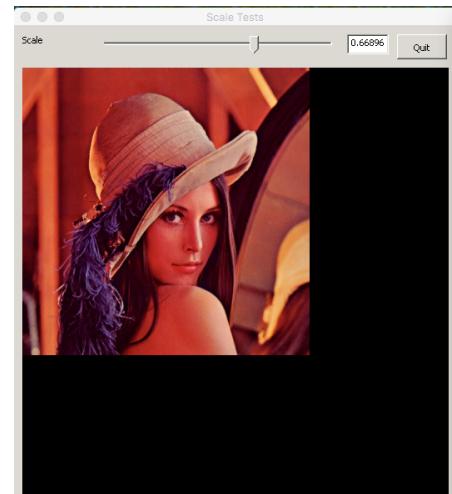
img1: rcvLoadImage %..../images/lena.jpg

factor: 1.0

drawBlk: rcvScaleImage factor

append drawBlk [img1]

...



## rcvTranslateImage

Sets the origin for drawing commands : Returns a Draw block

rcvTranslateImage: function [scaleValue [float!] translateValue [pair!] return: [block!]]

scaleValue: float! value to reduce or increase image size

translateValue : pair to translate image in X and Y direction

This function uses Draw Dialect and you have to add the image instance to the draw block.

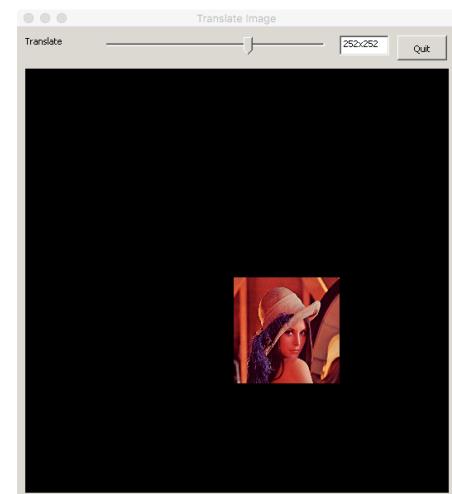
img1: rcvLoadImage %..../images/lena.jpg

factor: 0x0

drawBlk: rcvTranslateImage 0.25 factor

append drawBlk [img1]

...



## rcvRotateImage

Sets the clockwise rotation about a given point, in degrees : Returns a Draw block

rcvRotateImage: function [scaleValue [float!] translateValue [pair!] angle [float!] center [pair!] return: [block!]]

scaleValue: float! value to reduce or increase image size

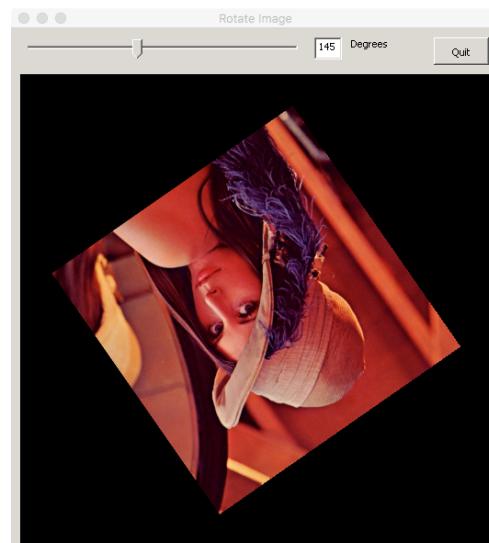
translateValue : pair to translate image in X and Y direction

angle: rotation of image in degrees

center: center of image rotation as pair! Default value 0x0

This function uses Draw Dialect and you have to add the image instance to the draw block.

```
img1: rcvLoadImage %.../..../images/lena.jpg  
iSize: img1/size  
centerXY: iSize / 2  
rot: 0.0  
drawBlk: rcvRotateImage 0.625 96x96 rot  
centerXY  
append drawBlk [img1]  
...
```



## rcvSkewImage

Sets a coordinate system skewed from the original by the given number of degrees

rcvSkewImage: function [scaleValue [float!] translateValue [pair!] x [number!] y [number!] return: [block!]]

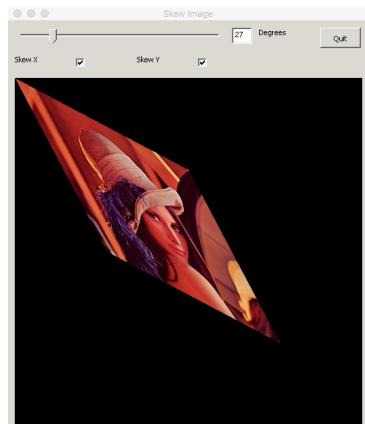
scaleValue: float! value to reduce or increase image size

translateValue : pair to translate image in X and Y direction

x: skew along the x-axis in degrees (integer! float!).

y: skew along the y-axis in degrees (integer! float!).

This function uses Draw Dialect and you have to add the image instance to the draw block.  
img1: rcvLoadImage %../../images/lena.jpg  
x: 0  
y: 0  
drawBlk: rcvSkewImage 0.5 0x0 x y  
append drawBlk [img1]



# Chamfer Distances

## rcvMakeGradient

**Makes a gradient matrix for contour detection (similar to Sobel) and returns max gradient value**

rcvMakeGradient: function [src [vector!]] dst [vector!] mSize [pair!] return: [integer!]]

src: integer matrix

dst: integer matrix

mSize: matrix size as a pair!

## rcvMakeBinaryGradient

**Makes a binary [0 1] matrix for contour detection**

rcvMakeBinaryGradient: function [src [vector!]] mat [vector!] maxG [integer!] threshold [integer!]]

src: integer matrix

mat: destination integer matrix

maxG : max gradient value

threshold : integer value for binary thresholding

## rcvFlowMat

**Calculates the distance map to binarized gradient**

rcvFlowMat: function [input [vector!]] output[vector!] scale [float!] return: [float!]]

input: float source matrix

output: destination matrix including distances

returns max distance

## rcvnrmalizeFlow

**Normalizes distance into 0..255 range according to scale value**

rcvnrmalizeFlow: function [input [vector!]] factor [float!]]

input: integer matrix

factor: value used for normalization such as max gradient value

## rcvGradient&Flow

**Creates an image including flow and gradient values**

rcvGradient&Flow: function [input1 [vector!]] input2 [vector!] dst [image!]]

input1: flow integer matrix

input2: gradient integer matrix

dst: red image for mixing flow and gradient

## rcvChamferDistance

**Selects a pre-defined chamfer kernel**

```
rcvChamferDistance: function [chamferMask [block!]] return: [block!]
Kernels calculated by Verwer, Borgefors and Thiel
cheessboard: copy [1 0 1 1 1 1]
chamfer3:    copy [1 0 3 1 1 4]
chamfer5:    copy [1 0 5 1 1 7 2 1 11]
chamfer7:    copy [1 0 14 1 1 20 2 1 31 3 1 44]
chamfer13:   copy [1 0 68 1 1 96 2 1 152 3 1 215 3 2 245 4 1 280 4 3 340 5 1 346 6 1 413]
```

## rcvChamferCreateOutput

**Creates a distance map (float!)**

```
rcvChamferCreateOutput: function [mSize [pair!]] return: [vector!]
```

mSize: matrix size as a pair value

## rcvChamferInitMap

Initializes distance map

```
rcvChamferInitMap: function [input [vector!] output [vector!]]
```

input: a binary [0/1] matrix

output: must be a vector of float!

If input value= 0, the point belongs to the object and thus the distance is 0.0

If input value= 1, the point is outside and the distance (-1.0) must be calculated

## rcvChamferCompute

**Calculates the distance map to binarized gradient**

```
rcvChamferCompute: function [output [vector!] chamfer [block!] mSize [pair!]]
```

output: float matrix created by rcvChamferInitMap function is used

chamfer: selected pre-defined kernel used for distance calculation (e.g. chamfer5)

## rcvChamferNormalize

**Normalizes distance map**

```
rcvChamferNormalize: function [output [vector!] value [integer!]]
```

# Dynamic Time Warping

Quoting wikipedia:

"In time series analysis, dynamic time warping (DTW) is an algorithm for measuring similarity between two temporal sequences which may vary in time or speed. For instance, similarities in walking patterns could be detected using DTW, even if one person was walking faster than the other, or if there were accelerations and decelerations during the course of an observation."

Applied to computer vision DTW is really useful if we want to compare shapes and decide if shapes are similar or not.

In redCV we use a basic DTW algorithm which is documented here : <https://nipunbatra.github.io/blog/2014/dtw.html>. Thanks to Nipun Batra for writing a clear python code.

The objective is to find a mapping between all points of x and y series. In the first step, we will find out the distance between all pair of points in the two signals. Then, in order to create a mapping between the two signals, we need to create a path. The path should start at (0,0) and want to reach (M,N) where (M, N) are the lengths of the two signals. To do this, we thus build a matrix similar to the distance matrix. This matrix would contain the minimum distances to reach a specific point when starting from (0,0). DTW value corresponds to (M,N) sum value.

## rcvDTWMin

**Minimal value between 3 values**

rcvDTWMin: function [x [number!] y [number!] z [number!]] return: [number!]]

## rcvDTWDistances

**Making a 2d matrix to compute distances between all pairs of x and y series**

rcvDTWDistances: function [x [block!] y [block!]] return: [vector!]]

x: a block! of number!

y: a block! of number!

Returns the distance matrix

## rcvDTWRun

**Making a 2d matrix to compute minimal distance cost**

rcvDTWRun: function [x [block!] y [block!] dMat [vector!]] return: [block!]

x: a block! of number!

y: a block! of number!

dMat: a matrix of distances

Returns the minimal distance matrix

## rcvDTWGetDTW

**Returns DTW value**

rcvDTWGetDTW: function [cMat [vector!]] return: [number!]] [

cMat: Minilam distance matrix

returns DTW value

## rcvDTWGetPath

Finds the path minimizing the distance

rcvDTWGetPath: function [x [block!] y [block!] cMat [vector!] return: [block!]

x: a block! of number!

y: a block! of number!

Returns optimal distance path

## rcvDTWCompute

Short-cut to get DTW value if you don't need distance and cost matrices

rcvDTWCompute: function [x [block!] y [block!] return: [number!]

x: a block! of number!

y: a block! of number!

Returns DTW value

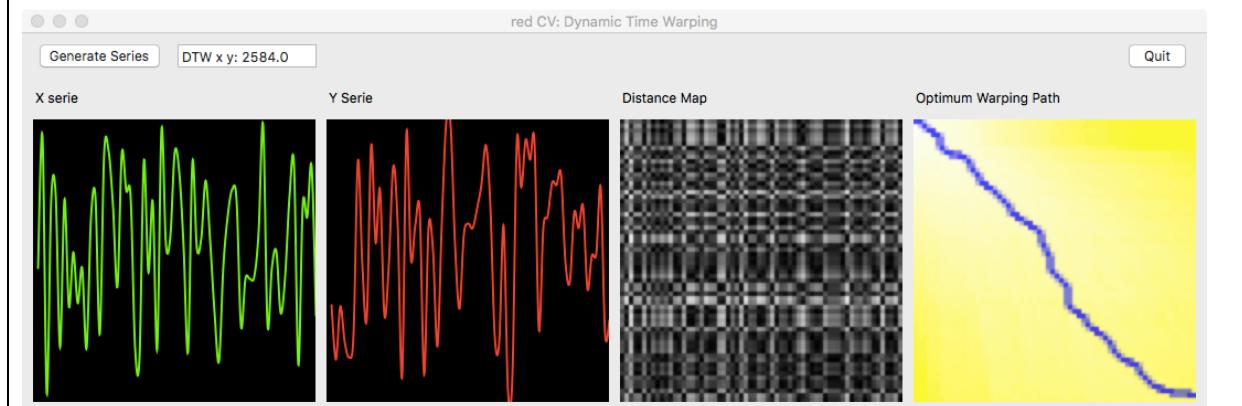
Code sample

dMatrix: rcvDTWDistances x y

cMatrix: rcvDTWRun x y dMatrix

dtw: rcvDTWGetDTW cMatrix

xPath: rcvDTWGetPath x y cMatrix



# Image enhancement

## rcvMakeTranscodageTable

Creates a transcoding 256 table for affine enhancement

rcvMakeTranscodageTable: function [n [percent!]] return: [vector!]

n: percent of values to exclude

This function is used by rcvContrastAffine method. See below.

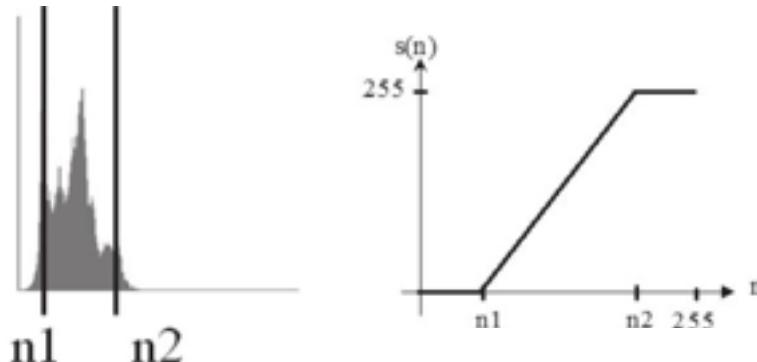
## rcvContrastAffine

Enhances image contrast with affine function

rcvContrastAffine: function [image [vector!] n [percent!]]

image: a 8-bit matrice

n: percent of values to exclude



$$S(n) = 0 \text{ if } n \leq n_1, \quad S(n) = 255 * (n - n_1) / (n_2 - n_1) \text{ if } n_1 < n < n_2 \text{ and } S(n) = 255 \text{ if } n \geq n_2$$

## rcvHistogramEqualization

This function performs histogram equalization on the input image array

rcvHistogramEqualization: function [ image [vector!] gLevels [integer!] ]

image: a 8-bit matrice

gLevels: number of gray levels in the new image

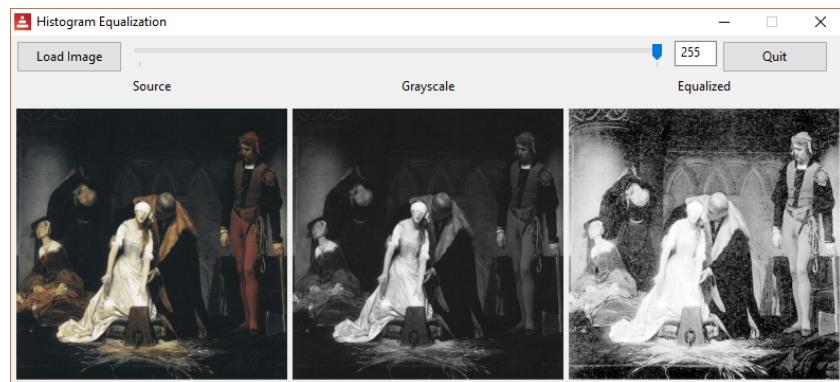
This algorithm performs first the histogram of the source image and then calculates the probability-density function of a pixel value  $n$ :  $p_1(n)$  is the probability of finding a pixel with the value  $n$  in the image. Then the following equation is applied

$$f(a) = D_m \frac{1}{Area_1} \sum_{i=0}^a H_c(a)$$

$H_c(a)$  is the histogram of the original image  $c$  and  $D_m$  is the number of gray levels in the new image  $b$ . Area is the size of the image.  $f(a)$  simply takes the probability density function for the

values in image b and multiplies this by the cumulative density function of the values in image c.

This function is useful for improving contrast in low-contrasted images or simply modifying the contrast of image.



# Thresholding

## rcv2BWFilter

**Binarization of RGB image according to threshold value**

rcv2BWFilter: function [src [image!] dst [image!] thresh [integer!]]

src: image

dst: image

thresh: threshold integer value

## rcvThreshold

**Applies fixed-level threshold to array elements. Images are processed as grayscale.**

rcvThreshold: function [src [image!] dst [image!] thresh [integer!] mValue [integer!]]

/binary /binaryInv /trunc /toZero /toZeroInv

src: image

dst: image

thresh: threshold integer value

mValue: maximal integer value

refinements are used for thresholding type

binary:dst(x,y) = mValue, if src(x,y)>threshold, 0, otherwise

binaryInv: dst(x,y) = 0, if src(x,y)>threshold, mValue, otherwise

trunc: dst(x,y) = threshold, if src(x,y)>threshold , src(x,y), otherwise

toZero: dst(x,y) = src(x,y), if src(x,y)>threshold, 0, otherwise

toZeroInv: dst(x,y) = 0, if src(x,y)>threshold, src(x,y), otherwise

## rcvInRange

**Extracts sub array from image according to lower and upper rgb values**

rcvInRange: function [src [image!] dst [image!] lower [tuple!] upper [tuple!] op [integer!]]

src: source image

dst: destination image

lower: lower tuple

upper: lower tuple

op: if op = 0 image is binarized else colors are extracted

## rcvInRangeMat

**Extracts sub array from matrix according to lower and upper values**

rcvInRangeMat: function [src [vector!] dst [vector!] lower [integer!] upper [integer!] op [integer!]]

src: source matrix

dst: destination matrix

lower: lower value

upper: lower upper

op: if op = 0 image is binarized else gray values are extracted

# Spatial filtering

Many filters are based on 2-D convolution. The 2-D convolution operation isn't extremely fast, unless you use small (3x3 or 5x5) filters. There are a few rules about the filter. Its size has to be generally uneven, so that it has a center, for example 3x3, 5x5, 7x7 or 9x9 are ok. Apart from using a kernel matrix, convolution operation also has a multiplier factor and a bias. After applying the filter, the factor will be multiplied with the result, and the bias added to it. So if you have a filter with an element 0.25 in it, but the factor is set to 2, all elements of the filter are multiplied by two so that element 0.25 is actually 0.5. The bias can be used if you want to make the resulting image brighter.

## rcvMakeGaussian

**Creates a Gaussian uneven kernel**

rcvMakeGaussian: function [kSize [pair!] return: [block!]]

kSize: uneven pair for kernel e.g 3x3

Creates a Gaussian uneven kernel with the following equation

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Where, x is the distance along horizontal axis measured from the origin, y is the distance along vertical axis measured from the origin and  $\sigma$  is the standard deviation of the distribution.

## rcvGaussianFilter

**Fast Gaussian 2D filter**

rcvGaussianFilter: function [src [image!] dst [image!]]

src: image

dst: image

Kernel is 3x3 and bias is equal to zero. For larger kernel please use rcvFilter2D.

knl: rcvMakeGaussian 11x11 rcvFilter2D src dst

## rcvConvolve

**Convolves an image with the kernel**

rcvConvolve: function [src [image!] dst [image!] kernel [block!] factor [float!] delta [float!]]

src: source image

dst: destination image

kernel: kernel matrix as block!

factor: multiplier factor as float!

delta: bias for image brightness

```
img1: rcvLoadImage %..../..images/lena.jpg
dst: rcvCreateImage img1/size
gaussian: [0.0 0.2 0.0
           0.2 0.2 0.2
           0.0 0.2 0.0]
rcvConvolve img1 dst gaussian 2.0 0.0
```

## rcvConvolveMat

**Convolves a 2-D matrix with the kernel**

rcvConvolveMat: function [src [vector!]] dst [vector!] mSize[pair!] kernel [block!] factor [float!] delta [float!]]

src: source matrix

dst: destination matrix

mSize: matrix size as a pair!

kernel: kernel matrix as block!

factor: multiplier factor as float!

delta: bias for image brightness

## rcvConvolveNormalizedMat

**Convolves a 2-D matrix with the kernel and applies a scale to result**

rcvConvolveNormalizedMat: function [src [vector!]] dst [vector!] mSize[pair!] kernel [block!] factor [float!] delta [float!]]

src: source matrix

dst: destination matrix

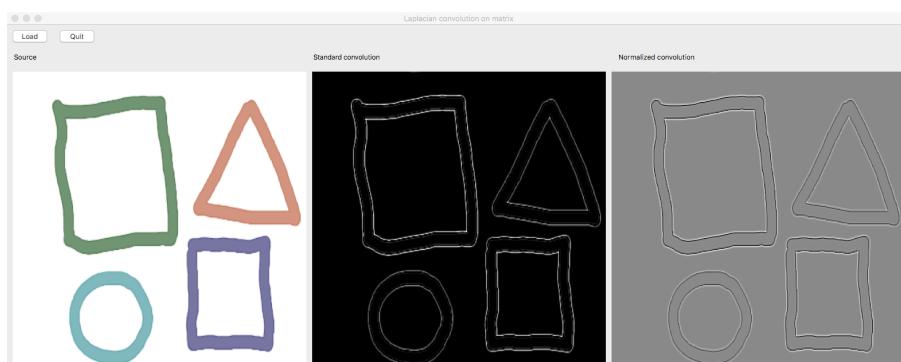
mSize: matrix size as a pair!

kernel: kernel matrix as block!

factor: multiplier factor as float!

delta: bias for image brightness

This function is two-pass: First, calculates minimal and maximal weighted sums resulting from the convolution process. This allows to calculate a scale equal to  $255 / (\text{maximal} - \text{minimal})$ . Then each matrix convoluted value is rescaled by  $(\text{value} - \text{minimal}) * \text{scale}$ . This means that whatever the sign of convoluted values, values are transformed into bytes [0..255] values.



## rcvFastConvolve

**Convolves 8-bit and 1-channel image with the kernel**

rcvFastConvolve: function [src [image!]] dst [image!] channel [integer!] kernel [block!] factor [float!] delta [float!]]

src: source image

dst: destination image

channel: image channel to process (RGB)

kernel: kernel matrix as block!

factor: multiplier factor as float!

delta: bias for image brightness

## rcvFilter2D

**Basic convolution filter**

rcvFilter2D: function [src [image!]] dst [image!] kernel [block!] delta [integer!]]

src: image

dst: image

kernel: kernel matrix as block!

delta: bias for image brightness

Similar to convolution but the sum of the weights is computed during the summation, and used to scale the result.

## rcvFastFilter2D

**Fast convolution filter**

rcvFastFilter2D: function [src [image!]] dst [image!] kernel [block!]]

src: image

dst: image

kernel: kernel matrix as block!

A faster version without controls on pixel value! Basically for 1 channel gray scaled image.  
The sum of the weights is computed during the summation, and used to scale the result

## rcvPointDetector

**Convolution allowing to find dots in image or matrix**

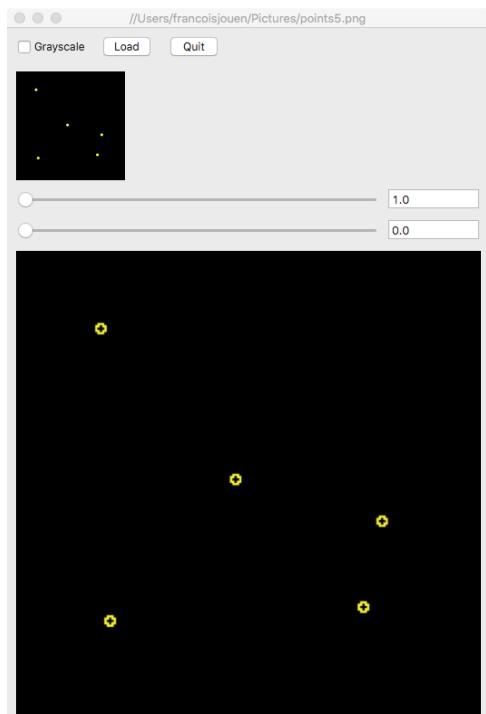
rcvPointDetector: function [src [image! vector!]] dst [image! vector!] param1 [float!] param2 [float!]

src: source image or matrix

dst: destination image or matrix

param1 : threshold value

param2 : luminance value



# Fast edge detection

You can, of course, build your own edges detectors by convolution (see rcvConvolve function). Here are included a set of classical and predefined filters which are fast and easy to use.

## First derivative filters

### rcvSobel

**Direct Sobel edges detection for image or matrix**

function [src [image! vector!] dst [image! vector!] iSize [pair!] direction [integer!]

src: image or matrix as vector

dst: image or matrix as vector

iSize: image or matrix size as pair

direction:

1: returns vertical gradient direction (Gx)

2: returns horizontal gradient direction (Gy)

3: both gradient directions by  $G = G_x + G_y$

4: both gradients estimated by  $G = \text{Sqrt}(G_x^2 + G_y^2)$

Used Hx, Hy and Ho (oblique) kernels

-1	0	1	
-2	0	2	
-1	0	1	

-1	-2	-1	
0	0	0	
1	2	1	

0	1	2	
-1	0	1	
-2	-1	0	

```
img1: rcvLoadImage %..../..../images/lena.jpg
```

```
img2: rcvCreateImage img1/size
```

```
img3: rcvCreateImage img1/size
```

```
rcv2Gray/average img1 img2 ; Grayscaled image
```

```
rcvSobel img2 img3 img1/size 4 ; Direct Sobel on image
```

```
img1: rcvLoadImage %..../..../images/lena.jpg
```

```
img2: rcvCreateImage img1/size
```

```
mat1: rcvCreateMat 'integer! intSize img1/size
```

```
mat2: rcvCreateMat 'integer! intSize img1/size
```

```
rcvImage2Mat img1 mat1 ; Converts image to 1 Channel matrix [0..255]
```

```
rcvSobel mat1 mat2 img1/size ; Sobel detector on Matrix
```

## rcvRoberts

**Robert's cross edges detection for image or matrix**

rcvRoberts: function [src [image! vector!]] dst [image! vector!] iSize [pair!] direction [integer!]

src: image or matrix as vector

dst: image or matrix as vector

iSize: image or matrix size as pair

factor: multiplier factor as float!

delta: bias for image brightness

direction:

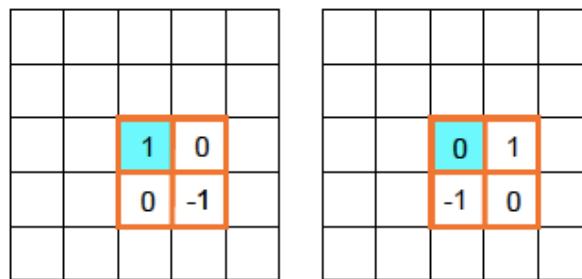
1: returns vertical gradient direction (Gx)

2: returns horizontal gradient direction (Gy)

3: both gradient directions by  $G = G_x + G_y$

4: both gradients estimated by  $G = \sqrt{G_x^2 + G_y^2}$

Used Hx and Hy kernels



## rcvPrewitt

**Computes an approximation of the gradient magnitude of the input image**

rcvPrewitt: function [src [image! vector!]] dst [image! vector!] iSize [pair!] direction [integer!]

src: image or matrix

dst: image or matrix

iSize: size of the image or the matrix

direction:

1: returns vertical gradient direction (Gx)

2: returns horizontal gradient direction (Gy)

3: both gradient directions by  $G = G_x + G_y$

4: both gradients estimated by  $G = \sqrt{G_x^2 + G_y^2}$

Used Hx and Hy kernels

-1	0	1	
-1	0	1	
-1	0	1	

-1	-1	-1	
0	0	0	
1	1	1	

## rcvKirsch

**Computes an approximation of the gradient magnitude of the input image**

rcvKirsch: function [src [image! vector!] dst [image! vector!] iSize [pair!] direction [integer!]]

src: image or matrix

dst: image or matrix

iSize: size of the image or the matrix

direction:

1: returns vertical gradient direction (Gx)

2: returns horizontal gradient direction (Gy)

3: both gradient directions by  $G = G_x + G_y$

4: both gradients estimated by  $G = \sqrt{G_x^2 + G_y^2}$

Used Hx and Hy kernels

-3	-3	5	
-3	0	5	
-3	-3	5	

-3	-3	-3	
-3	0	-3	
5	5	5	

## rcvGradNeumann

**Computes the discrete gradient by forward finite differences and Neumann boundary conditions**

rcvGradNeumann: function [src [image!] d1 [image!] d2 [image!]]

src: source image

d1: image for derivative along the x axis

d2: image derivative along the y axis

## rcvDivNeumann

**Computes the divergence by backward finite differences**

rcvDivNeumann: function [src [image!] d1 [image!] d2 [image!]]

src: source image

d1: image for derivative along the x axis

d2: image derivative along the y axis

## Second derivative filters

These filters use partial second derivative of an image or a matrix according to the equations

$$\left( \frac{\partial^2 I(x,y)}{\partial x^2} \right) \quad \left( \frac{\partial^2 I(x,y)}{\partial y^2} \right)$$

In x direction: and in Y direction:

## rcvDerivative2

**A fast approximation of the second derivative of an image**

rcvDerivative2: function [src [image! vector!] dst [image! vector!] iSize [pair!] factor [float!]

direction [integer!]

src: image or matrix

dst: image or matrix

iSize: size of the image or the matrix

Factor: multiplier factor as float!

direction:

1: returns vertical gradient direction (Gx)

2: returns horizontal gradient direction (Gy)

3: both gradient directions by G= Gx + Gy

Used Hx and Hy kernels

Hx Kernel			Hy Kernel		
0	0	0	0	1	0
1	-2	1	0	-2	0
0	0	0	0	1	0

## rcvLaplacian

Computes the Laplacian of an image or matrix. The Laplacian is an approximation of the second derivative of an image

rcvLaplacian: function [src [image! vector!] dst [image! vector!] iSize [pair!] connexity [integer!]

src: image or matrix

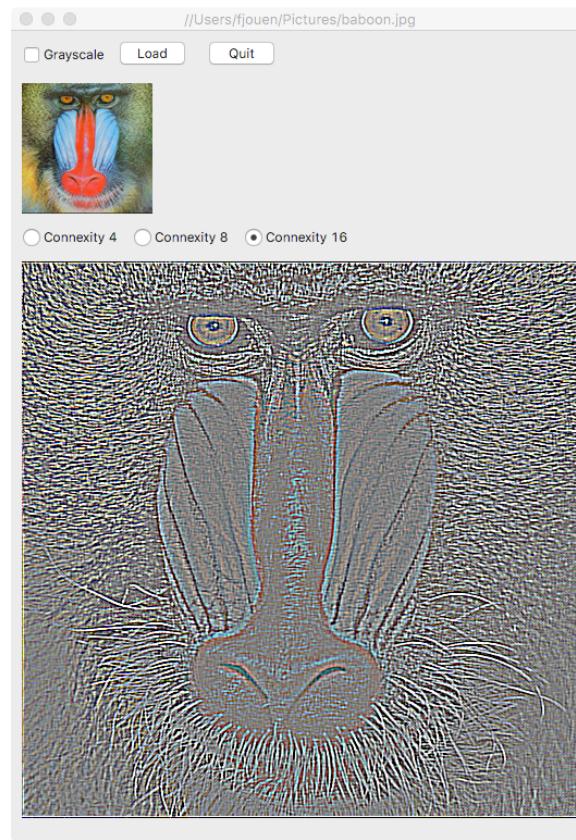
dst: image or matrix

iSize: size of the image or the matrix

connexity: neighbor pixels (4, 8 16)

Used kernels for 4, 8 or 16 connexity

$\begin{matrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{matrix}$	$\begin{matrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{matrix}$	$\begin{matrix} -1 & 0 & 0 & -1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ -1 & 0 & 0 & -1 \end{matrix}$
--	---	--



# Lines detection

RedCV includes Hough transform operator. The Hough transformation is a great way to detect lines in an image and it is quite useful for a number of computer vision tasks (see [http://en.wikipedia.org/wiki/Hough\\_transform](http://en.wikipedia.org/wiki/Hough_transform)).

You can find here <http://www.keymolen.com/2013/05/hough-transformation-c-implementation.html> a very clear and detailed explanation. Thanks a lot to Bruno Keymolen for his original C++ code.

## rcvMakeHoughAccumulator

**Creates Hough accumulator**

rcvMakeHoughAccumulator: func [w [integer!] h [integer!] return: [vector!]]

w: source image width

h: source image height

## rcvGetAccumulatorSize

**Gets Hough space accumulator size**

rcvGetAccumulatorSize: function [acc [vector!]] return: [pair!]

## rcvHoughTransform

**Makes Hough transform**

rcvHoughTransform: function [mat [vector!] accu [vector!] w [integer!] h [integer!]]

## rcvGetHoughLines

**Gets lines in the accumulator according to threshold**

rcvGetHoughLines: func [accu [vector!] img [image!] threshold [integer!] lines [block!]]

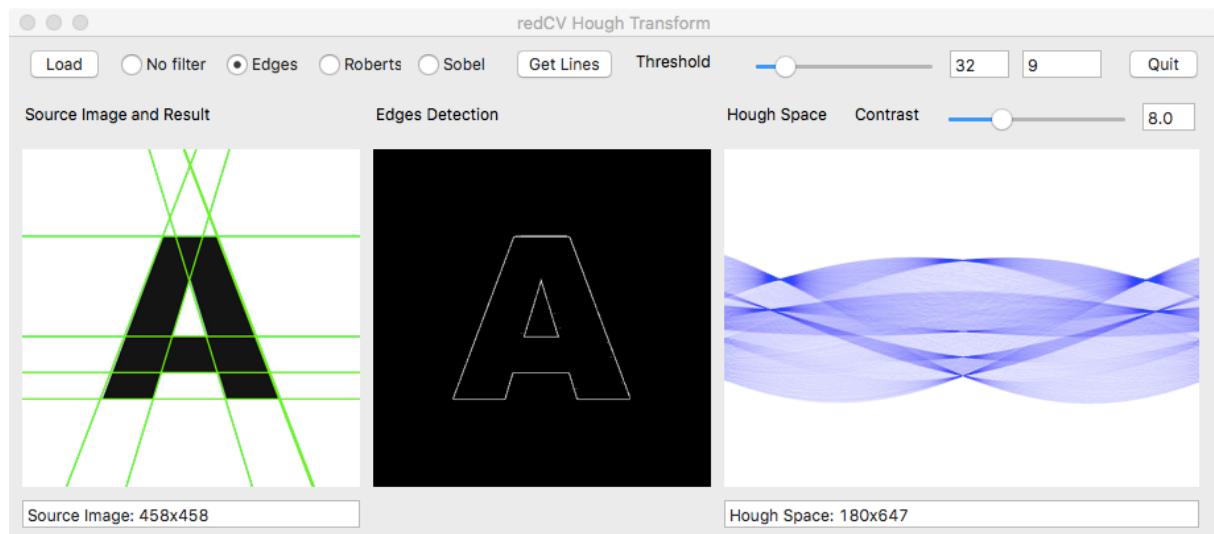
## rcvHough2Image

**Makes Hough space as red image**

rcvHough2Image: function [mat [vector!] dst [image!] contrast [float!]]

## Code Sample

rcv2BW edges bw	; B&W image [0 255]
rcvImage2Mat bw mat	; B&W image to mat
acc: rcvMakeHoughAccumulator imgW imgH	; makes Hough accumulator
rcvHoughTransform mat acc imgW imgH 128	; performs Hough transform
hSpace: rcvCreateImage rcvGetAccumulatorSize acc	; creates Hough space image
rcvHough2Image acc hSpace contrast	; shows Hough space



# Shape detection

RedCV includes Freeman chain code operator. The basic principle of chain codes is to separately encode each connected component, or "blob", in the image. For each such region, a point on the boundary is selected and its coordinates are transmitted. The encoder then moves along the boundary of the region and, at each step, transmits a number representing the direction of this movement.

5 northwest	6 north	7 northeast
4 west	pixel	0 east
3 southwest	2 south	1 southeast

You need a binary matrix [0..1] or [0..255] corresponding to your source image. See `rcvMakeBinaryMat` function.

## rcvMatGetBorder

Gets pixels that belong to shape border

```
function [mat [vector!] matSize [pair!] value [integer!] border [block!]]  
mat: source binary matrix  
matSize: matrix size as pair  
value: pixel value (default 1)  
border: a block to store pixels direction
```

## rcvMatGetChainCode

Gets Freeman Chain code

```
function [mat [vector!] matSize [pair!] coord [pair!] value [integer!] return: [integer!]  
mat: source binary matrix  
matSize: matrix size as pair  
coord: pixel x and y coordinates  
value: pixel value (default 1)
```

The function uses the current pixel and explores pixel neighbors in order to get the direction of the next pixel. Top-left pixel (first value of the border block) is used as starting coordinate, then the encoder clockwise processes next pixels.

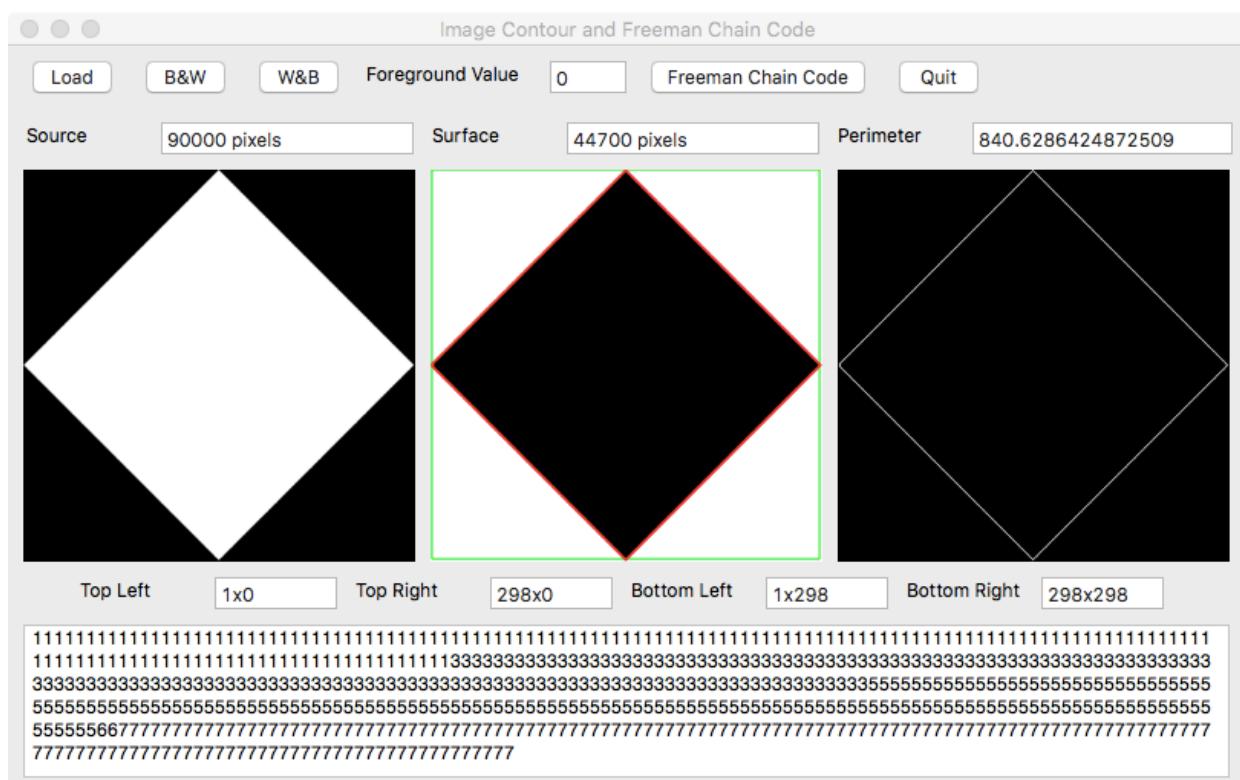
ATTENTION: you have to write a function to store chain codes such as (see `imagecontour.red` sample. Visited is a temporary matrix used to store visited pixels)

```
getCodes: does [  
    visited: rcvCreateMat 'integer! 32 matSize  
    border: copy []  
    rcvMatGetBorder bmat matSize 1 border  
    foreach p border [rcvSetInt2D visited matSize p 255]  
    count: length? border  
    p: first border  
    i: 1
```

```

s: copy ""
clear r/text
perimeter: 0.0
while [i < count] [
    d: rcvMatGetChainCode visited matSize p 255
    rcvSetInt2D visited matSize p 0 ; pixel is visited
    if d >= 0 [append s form d]; only external pixels -1: internal
    switch d [
        0      [p/x: p/x + 1 perimeter: perimeter + 1.0] ; east
        1      [p/x: p/x + 1 p/y: p/y + 1 perimeter: perimeter + sqrt 2] ; southeast
        2      [p/y: p/y + 1 perimeter: perimeter + 1.0] ; south
        3      [p/x: p/x - 1 p/y: p/y + 1 perimeter: perimeter + sqrt 2] ; southwest
        4      [p/x: p/x - 1 perimeter: perimeter + 1.0] ; west
        5      [p/x: p/x - 1 p/y: p/y - 1 perimeter: perimeter + sqrt 2] ; northwest
        6      [p/y: p/y - 1 perimeter: perimeter + 1.0] ; north
        7      [p/x: p/x + 1 p/y: p/y - 1 perimeter: perimeter + sqrt 2] ; northeast
    ]
    i: i + 1
]

```



# Mathematical morphology

## rcvCreateStructuringElement

The function allocates and fills a block, which can be used as a structuring element in the morphological operations

cvCreateStructuringElement: function [kSize [pair!]] return: [block!] /rectangle /cross]  
kSize: Kernel size (e.g. 3x3)

Refinement is used to create a cross-shaped element or a rectangular element

## rcvErode

Erodes image by using structuring element

rcvErode: function [ src [image!] dst [image!] kSize [pair!] kernel [block!] ]

src: image

dst: image

kSize: kernel size as pair!

Kernel: block generated by cvCreateStructuringElement or customed structuring element

The function rcvErode erodes the source image using the specified structuring element that determines the shape of a pixel neighborhood over which the minimum is taken:

```
dst=erode(src,element): dst(x,y)=min((x',y') in element)src(x+x',y+y')
```

## rcvErodeMat:

Erodes matrix by using structuring element

rcvErodeMat: function [ src [vector!] dst [vector!] mSize [pair!] kSize [pair!] kernel [block!] ]

src: matrix

dst: matrix

mSize: matrix size as pair!

kSize: kernel size as pair!

## rcvDilate

Dilates image by using structuring element

rcvDilate: function [ src [image!] dst [image!] kSize [pair!] kernel [block!] ]

src: image

dst: image

kSize: kenel size as pair!

kernel: block generated by cvCreateStructuringElement or customed structuring element

The function rcvDilate dilates the source image using the specified structuring element that determines the shape of a pixel neighborhood over which the maximum is taken:

```
dst=dilate(src,element): dst(x,y)=max((x',y') in element)src(x+x',y+y')
```

## rcvDilateMat

Dilates matrix by using structuring element

rcvDilateMat: function [ src [vector!] dst [vector!] mSize [pair!] kSize [pair!] kernel [block!]]

src: matrix

dst: matrix

mSize: matrix size as pair!

kSize: kernel size as pair

## rcvOpen

Erodes and Dilates image by using structuring element

rcvOpen: function [ src [image!] dst [image!] kSize [pair!] kernel [block!]]

src: image

dst: image

kSize: kenel size as pair!

kernel: block generated by cvCreateStructuringElement or customed structuring element

## rcvClose

Dilates and Erodes image by using structuring element

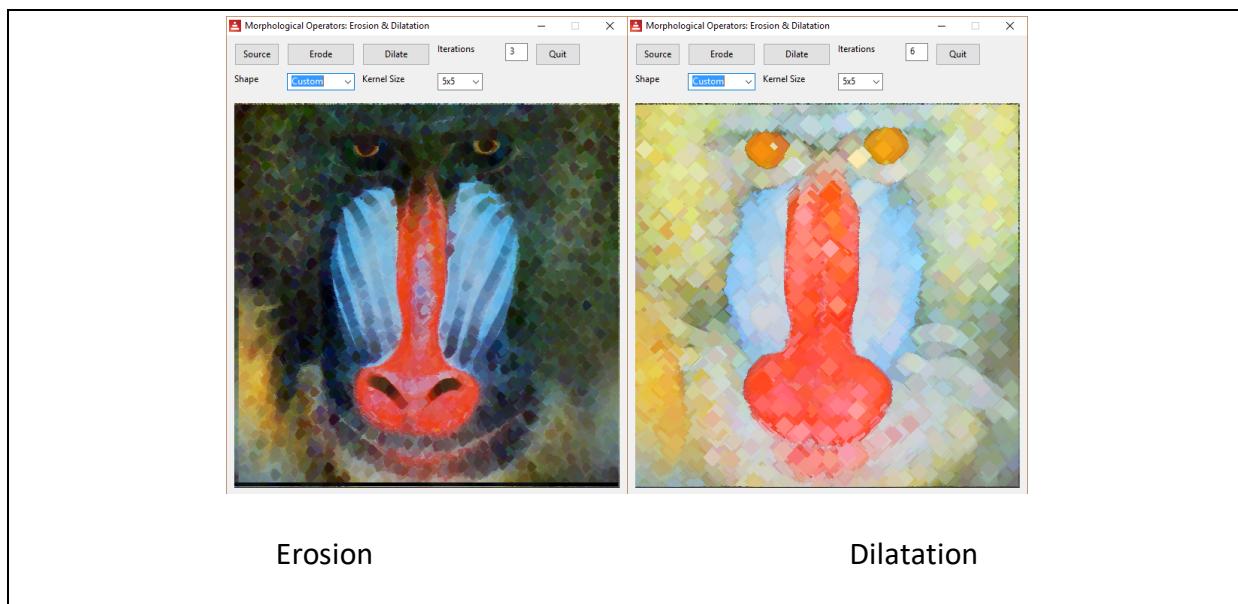
rcvClose: function [ src [image!] dst [image!] kSize [pair!] kernel [block!]]

src: image

dst: image

kSize: kenel size as pair!

kernel: block generated by cvCreateStructuringElement or customed structuring element



## rcvMGradient

**Performs advanced morphological transformations using erosion and dilatation as basic operations**

rcvMGradient: function [ src [image!] dst [image!] kSize [pair!] kernel [block!] /reverse]

src: image

dst: image

kSize: kernel size as pair!

kernel: block generated by cvCreateStructuringElement or customized structuring element

```
dst=dilate src – erode src
```

```
/reverse : dst=erode src – dilate src
```

## rcvTopHat

**Performs advanced morphological transformations**

rcvTopHat: function [ src [image!] dst [image!] kSize [pair!] kernel [block!] ]

src: image

dst: image

kSize: kernel size as pair!

kernel: block generated by cvCreateStructuringElement or customized structuring element

```
dst =src – open src dst
```

## rcvBlackHat

**Performs advanced morphological transformations**

rcvTopHat: function [ src [image!] dst [image!] kSize [pair!] kernel [block!] ]

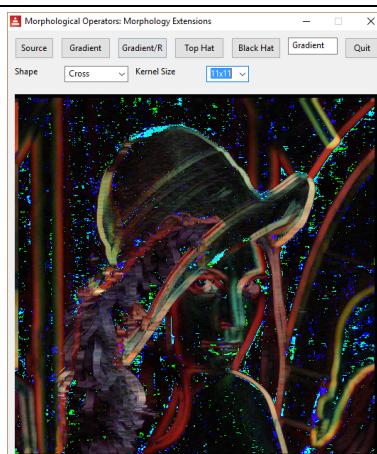
src: image

dst: image

kSize: kernel size as pair!

kernel: block generated by cvCreateStructuringElement or customized structuring element

```
dst = open src dst - src
```



## rcvMMean

**Means image by using structuring element**

rcvMMean: function [ src [image!] dst [image!] kSize [pair!] kernel [block!]]

src: image

dst: image

kSize: kernel size

kernel: block generated by cvCreateStructuringElement or customed structuring element

# GUI Functions

Some functions for RedCV quick test. Functions are pure Red code. Routines are not required. These functions can also be used for displaying temporary images.

## rcvNamedWindow

**Creates a window**

rcvNamedWindow: function [title [string!]] return: [window!]]

title: Windows title as a string

window is returned a face datatype!

## rcvDestroyWindow

**Destroys a created window**

rcvDestroyWindow: function [window [face!]]

window: Points to a window created by rcvNamedWindow

## rcvDestroyAllWindows

**Destroys all windows**

rcvDestroyAllWindows: function []

## rcvResizeWindow

**Sets window size**

rcvResizeWindow: function [window [face!] wSize [pair!]]

## rcvMoveWindow

**Sets window position**

rcvMoveWindow: function [window [face!] position [pair!]]

## rcvShowImage

**Shows image in window**

rcvShowImage: function [window [face!] image [image!]]

```
#include %../libs/redcv.red
img1: rcvLoadImage %../images/lena.jpg
s1: rcvNamedWindow "Source"
rcvShowImage s1 img1 wait 2
rcvMoveWindow s1 20x60 wait 2
rcvResizeWindow s1 512x512 wait 2
rcvDestroyWindow s1
do-events
```

# Random Generator

## Continuous Laws

### randFloat

Returns a decimal value between 0 and 1. Base 16 bit

randFloat: function[]

### randUnif

Uniform law

randUnif: function [i [float!] j [float!]]

i: float value

### randExp

Exponential law

randExp: function []

### randExpm

Exponential law with a l degree

randExpm: function [l [float!]]

l: float value (e.g. 1.0)

### randNorm

Normal law

randNorm : function [A [float!]]

A: float value (e.g. 1.0)

### randLognorm

Lognormal law

randLognorm: function [a [float!] b [float!] z [float!]]

a: float value

b: float value

z: float value

### randGamma

Gamma law

randGamma: func [k [integer!] l [float!] i]

k: integer value

l: float value

## randDisc

**Geometric law in a disc**

randDisc: function []

## randRect

**Geometric law in a rectangle**

randRect: function [a [float!] b [float!] c [float!] d [float!]]

a: float value

b: float value

c: float value

d: float value

## randChi2

**Chi square law**

randChi2: function [v [integer!]]

v: integer value (e.g. 2)

## randErlang

**Erlang law**

randErlang: function [n [integer!]]

n: integer value (e.g. 2)

## randStudent

**Student law**

randStudent: function [ n [integer!] z [float!]]

n: integer value (e.g. 3)

z: float value (e.g. 1.0)

## randFischer

**Fisher law (e.g 1 1)**

randFischer: function [ n [integer!] m [integer!]]

n: integer value (e.g. 1)

m: integer value (e.g. 1)

## randLaplace

**Laplace law**

randLaplace: function [a [float!] /local u1 u2]

a: float value (e.g. 1.0)

## randBeta

### Beta law

randBeta: function [a [integer!] b [integer!]]

a: integer value (e.g. 1)

b: integer value (e.g. 1)

## randWeibull

### Weibull law

randWeibull: function [a [float!] l [float!]]

a: float value (e.g. 1.0)

l: float value (e.g. 1.0)

## randRayleigh

### Rayleigh law

randRayleigh: function []

## Discrete Laws

## randBernoulli

### Bernoulli law

randBernoulli: function [p [float!]]

p: float value (e.g. 0.5)

## randBinomial

### Binomial law

randBinomial: function [n [integer!] p [float!]]

n: integer value (e.g. 1)

p: float value (e.g. 0.5)

## randBinomialneg

### Binomial negative law (e.g. 1 0.5)

randBinomialneg: function [n [integer!] p [float!]]

n: integer value (e.g. 1)

p: float value (e.g. 0.5)

## randGeo

### Geometric law

randGeo: func [p [float!]]

p: float value (e.g. 0.25)

## randPoisson

### Poisson law

randPoisson: function [l [float!]]

l: float value (e.g. 1.5)