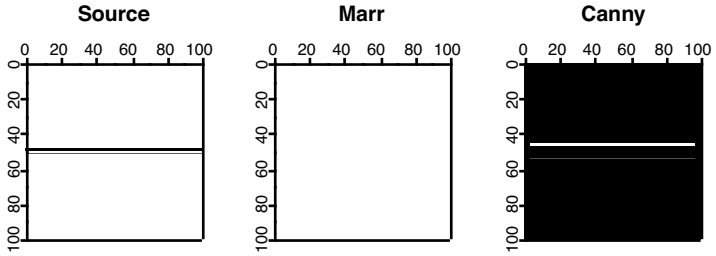
```
NewImage s2
ImageEdgeDetection/M=1/S=3 Canny, sampleEdge
Duplicate/O M_ImageEdges s3
NewImage s3
```

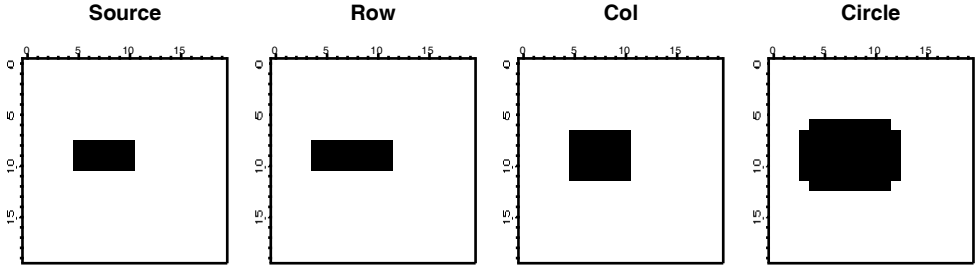


Note that the Marr detector completely misses the edge with the smoothing setting set to 1. Also, the position of the edge moves away from the true edge with increased smoothing in the Canny detector.

Morphological Operations

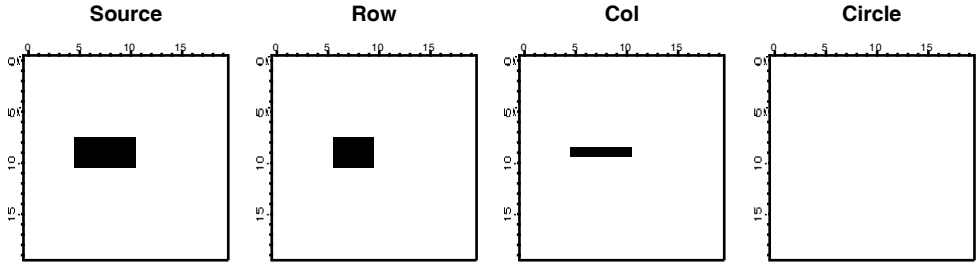
Morphological operators are tools that affect the shape and boundaries of regions in the image. Starting with dilation and erosion, the typical morphological operation involves an image and a structure element. The structure element is normally much smaller in size than the image. Dilation consists of reflecting the structure element about its origin and using it in a manner similar to a convolution mask. This can be seen in the next example:

```
Make/B/U/N=(20,20) source=0
source[5,10][8,10]=255                  // source is a filled rectangle
NewImage source
Imagemorphology /E=2 BinaryDilation source// dilation with 1x3 element
Duplicate M_ImageMorph row
NewImage row                        // display the result of dialation
Imagemorphology /E=3 BinaryDilation source// dilation by 3x1 column
Duplicate M_ImageMorph col
NewImage col                              // display column dilation
Imagemorphology /E=5 BinaryDilation source// dilation by a circle
NewImage M_ImageMorph                     // display circle dilation
```



The result of erosion is the set of pixels x, y such that when the structure element is translated by that amount it is still contained within the set.

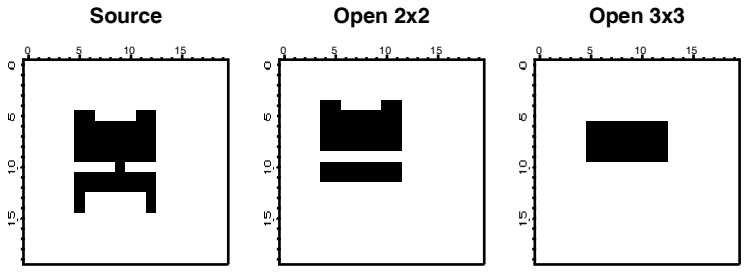
```
Make/B/U/N=(20,20) source=0
source[5,10][8,10]=255                  // source is a filled rectangle
NewImage source
Imagemorphology /E=2 BinaryErosion source// erosion with 1x3 element
Duplicate M_ImageMorph row
NewImage row                            // display the result of erosion
Imagemorphology /E=3 BinaryErosion source// erosion by 3x1 column
Duplicate M_ImageMorph col
NewImage col                            // display column erosion
Imagemorphology /E=5 BinaryErosion source// erosion by a circle
NewImage M_ImageMorph                   // display circle erosion
```



We note first that erosion by a circle erased all source pixels. We get this result because the circle structure element is a 5x5 "circle" and there is no x, y offset such that the circle is completely inside the source. The row and the col images show erosion predominantly in one direction. Again, try to imagine the 1x3 structure element (in the case of the row) sliding over the source pixels to produce the erosion.

The next pair of morphological operations are the opening and closing. Functionally, opening corresponds to an erosion of the source image by some structure element (say E), and then dilating the result using the same structure element E again. In general opening has a smoothing effect that eliminates small (narrow) protrusions as we show in the next example:

```
Make/B/U/N=(20,20) source=0
source[5,12][5,14] = 255
source[6,11][13,14] = 0
source[5,8][10,10] = 0
source[10,12][10,10] = 0
source[7,10][5,5] = 0
NewImage source
ImageMorphology /E=1 opening source // open using 2x2 structure element
Duplicate M_ImageMorph OpenE1
NewImage OpenE1
ImageMorphology /E=4 opening source // open using a 3x3 structure element
NewImage M_ImageMorph
```

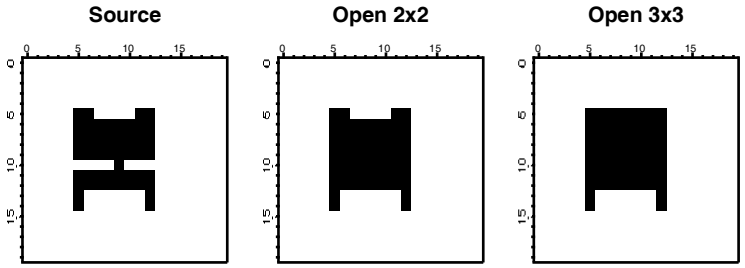


As you can see, the 2x2 structure element removed the thin connection between the top and the bottom regions as well as the two protrusions at the bottom. On the other hand, the two protrusions at the top were large enough to survive the 2x2 structure element. The third image shows the result of the 3x3 structure element which was large enough to eliminate all the protrusions but also the bottom region as well.

The closing operation corresponds to a dilation of the source image followed by an erosion using the same structure element.

```
Make/B/U/N=(20,20) source=0
source[5,12][5,14] = 255
source[6,11][13,14] = 0
source[5,8][10,10] = 0
source[10,12][10,10] = 0
source[7,10][5,5] = 0
NewImage source
ImageMorphology /E=4 closing source // close using 3x3 structure element
Duplicate M_ImageMorph CloseE4
NewImage CloseE4
```

```
ImageMorphology /E=5 closing source // close using 5x5 structure element
NewImage M_ImageMorph
```



The center image above corresponds to a closing using a 3x3 structure element which appears to be large enough to close the gap between the top and bottom regions but not sufficiently large to fill the gaps between the top and bottom protrusions. The image on the right was created with a 5x5 "circle" structure element, which was evidently large enough to close the gap between the protrusions at the top but not at the bottom.

There are various definitions for the Top Hat morphological operation. Igor's Top Hat calculates the difference between an eroded image and a dilated image. Other interpretations include calculating the difference between the image itself and its closing or opening. In the following example we illustrate some of these variations.

```
Duplicate root:images:mri source
ImageMorphology /E=1 tophat source  // close using 2x2 structure element
Duplicate M_ImageMorph tophat
NewImage tophat
ImageMorphology /E=1 closing source // close using 3x3 structure element
Duplicate M_ImageMorph closing
closing-=source
NewImage closing
ImageMorphology /E=1 opening source // close using 3x3 structure element
Duplicate M_ImageMorph opening
opening=source-opening
NewImage opening
```