

Edge Detection

In an image, an edge is characterized by a sudden sharp change in intensity of pixel values. Thus, edges are high frequency components. So, they can be detected by differentiating the image. Digitally, differentiation is defined to be the following difference operation.

First order differentiation along x direction:

$$f'(x) = f(x+1) - f(x) \quad (1)$$

Second order differentiation along x direction:

$$f''(x) = f(x+1) + f(x-1) - 2f(x, y) \quad (2)$$

Roberts and Sobel are first order (gradient) edge detectors. These are good in detecting edges in the form of step or ramp.

Roberts cross gradient operator masks are as follows:

$$\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$
$$\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

In a Sobel mask, the closer pixels are given more importance than the diagonal pixels. Sobel operator masks are of the form:

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

The standard way is to detect edges along horizontal and vertical directions separately using the respective masks and then adding the two resultant images.

The second order edge detectors like the Laplacian, are good to detect fine details in an image. But, these also enhance spurious noise. The Laplacian derivative is of the form

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \quad (3)$$

Using the definition of second derivative, we get

$$\nabla^2 f = f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x, y) \quad (4)$$

The corresponding mask is given below:

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

If the image consists of lot of noise, then a smoothening operation can precede edge detection to prevent the detection of false edges.

Application

Edges contain the main structural features of an image. There are many applications of detecting edges like identifying objects in a scene, segmentation, etc. When the edges of an image are added to the original image, there is significant image enhancement.