EDGE DETECTION

Edges are abrupt changes in intensity, discontinuity in image brightness or contrast; usually edges occur on the boundary of two regions.

Figure: Original image (left) and edge (right)

Edge detection is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in brightness. Edge detection is used for image segmentation and data extraction in areas such as image processing, computer vision, and machine vision.

Use of Edge Detection

- Reduce unnecessary information in the image while preserving the structure of the image.
- Extract important features of an image such as corners, lines, and curves.
- Edges provide strong visual clues that can help the recognition process.

Here are some of the masks for edge detection.

- Prewitt Operator
- Sobel Operator
- Canny Edge Detector

PREWITT OPERATOR:

Prewitt operator is used for edge detection in an image. The Prewitt operator detects image intensity changes in the horizontal and vertical directions. By combining the horizontal and vertical gradients, edges in any direction can also be detected. For vertical Edges

Mask for detection of vertical edges

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

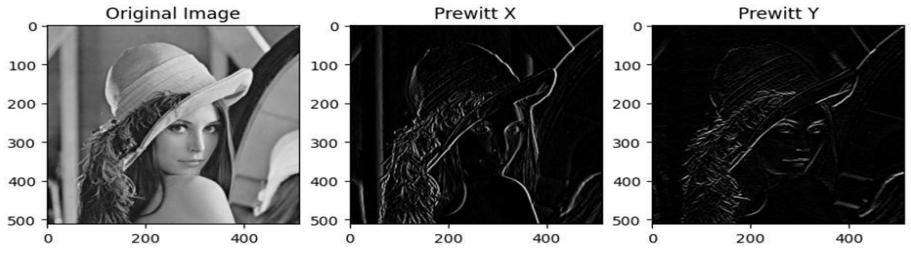
The above mask detects vertical edges because the middle column contains zeros, making it sensitive to intensity changes in the horizontal direction. When you will convolve this mask on an image, it will give you the vertical edges in an image.

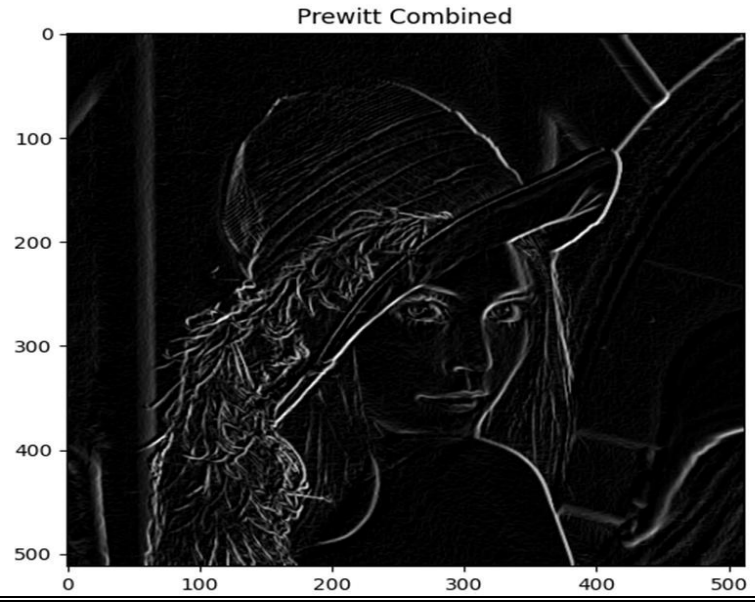
Horizontal Edges direction

Mask for detection of horizontal edges

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

Above mask will find edges in horizontal direction and it is because that zeros column is in horizontal direction. When you will convolve this mask onto an image it would prominent horizontal edges in the image.





SOBEL OPERATOR:

The Sobel operator is a first-order gradient-based edge detection operator used to detect intensity changes in an image. It calculates the image gradient in both horizontal and vertical directions. The Sobel operator computes horizontal (Gx) and vertical (Gy) gradients. These gradients can be combined to detect edges in any direction.

- Vertical direction
- Horizontal direction

The main difference between Prewitt and Sobel operators is that the Sobel operator assigns greater weight (2) to the centre row or column, giving more importance to neighbouring pixels. This improves edge detection and reduces the effect of noise.

For vertical Edges

Vertical Mask of Sobel Operator

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

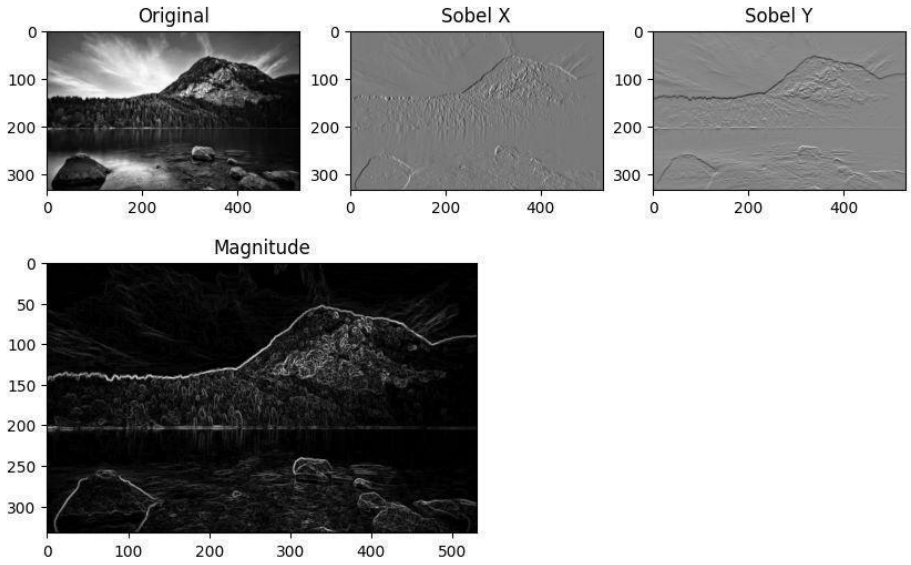
This mask works exactly same as the Prewitt operator vertical mask. There is only one difference that is it has “2” and “-2” values in center of first and third column. When applied on an image this mask will highlight the vertical edges.

Horizontal Edges direction

Horizontal Mask of Sobel Operator

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

Above mask will find edges in horizontal direction and it is because that zeros column is in horizontal direction. When you will convolve this mask onto an image it would prominent horizontal edges in the image. The only difference between it is that it have 2 and -2 as a centre element of first and third row.



As you can see that in the first picture on which we apply vertical mask, all the vertical edges are more visible than the original image. Similarly in the second picture we have applied the horizontal mask and in result all the horizontal edges are visible.

So in this way you can see that we can detect both horizontal and vertical edges from an image. Also if you compare the result of sobel operator with Prewitt operator, you will find that sobel operator finds more edges or make edges more visible as compared to Prewitt Operator. This is because in sobel operator we have allotted more weight to the pixel intensities around the edges.

CANNY EDGE DETECTOR

The Canny edge detector is a multi-stage algorithm that provides a robust solution to edge detection problems. It includes the following steps:

- **Gaussian Blur**: Smooth the image to reduce noise using a Gaussian filter.
- Gaussian Blur Kernel $= \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$
- **Gradient Calculation**: Compute the intensity gradients of the image using methods like Sobel or Prewitt.
- **Non-Maximum Suppression**: Thin out the edges by suppressing all gradients that are not local maxima.
- **Double Threshold**: Identify strong and weak edges based on threshold values.
- **Edge Tracking by Hysteresis**: Finalize the edge detection by connecting weak edges to strong edges if they are part of the same edge segment.

Original image

Edges detected

COMPARISON

S.NO	FEATURE	PREWITT OPERATOR	SOBEL OPERATOR	CANNY EDGE DETECTOR
1.	Type	Gradient-based edge detector	Gradient-based edge detector	Multi-stage edge detector
2.	Kernel Size	3 × 3	3 × 3	Gaussian filter + Sobel operator
3.	Noise Sensitivity	High	Moderate	Low
4.	Edge Detection	Detects horizontal and vertical edges	Detects horizontal and vertical edges with stronger edge response	Detects thin, accurate, and continuous edges
5.	Edge Quality	Moderate	Better than Prewitt	Excellent
6.	Accuracy	Moderate	High	Very High
7.	Computational Cost	Low	Moderate	High
8.	Advantages	Simple and easy to implement	Better edge detection and improved noise suppression	High accuracy with excellent noise reduction

Prewitt < Sobel < Canny (in terms of edge detection accuracy and noise immunity).