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A Comparison of Sobel and Prewitt Edge Detection Operators

Sanaa Said Al Rawahi*[1]

[1]Department of General Foundation, Al-Zahraa College for Women, Muscat, Oman.
*Corresponding Author.

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Abstract

This paper presents a comparative analysis of Sobel and Prewitt edge detection operators, focusing on their performance in detecting edges in digital images. Both methods are widely utilized in image processing to enhance and identify object boundaries. The study employs the Berkeley Segmentation Dataset 500 (BSDS500) for evaluation and MATLAB for implementation. Key performance metrics such as accuracy and execution time are analyzed. Results indicate that while Prewitt outperforms Sobel in terms of edge clarity and precision, Sobel shows a slight advantage in computational efficiency. This research provides valuable insights into the selection of edge detection techniques for various image processing applications.

Keywords: Edge Detection, Sobel Operator, Prewitt Operator, Image Processing, MATLAB Implementation.

1. Introduction

Edge Detection is a method that identifies the boundaries between two homogenous picture areas with varying brightness levels [1]. Detecting edges and corners in a single picture may assist reduce the size of the data stream and also aid in well-matched operations such as image restoration and so on [2].

Traditional edge detection uses operators, a two-dimensional filter. An image's edge appears when the gradient is highest. The operator finds the edges by finding big gradients. Edge recognition in noisy pictures is challenging because both edges and noise include high-frequency content. Attempts to minimize noise result in deformed edges. In this case, the operator can average enough data to filter out localized noise. However, the intensity shift is not usually a step change. This research attempts to explore the most widely used technique of edge detection: Sobel and prewitt [1],[3].

1.1. procedural stages for edge detection

Detecting the edge involves four steps, which are shown in Figure1:

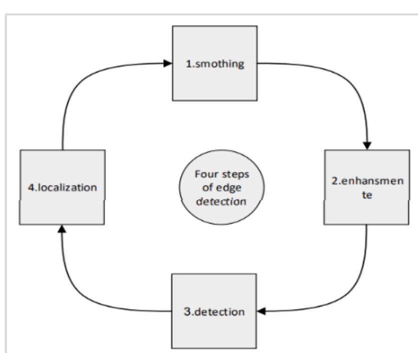

Figure 1: Edge Detection Phases[4]

- Smoothing: This phase involves filtering the picture to remove noise, which improves the effectiveness of the edge detector.
- Enhancement**:** This phase is included in the process of increasing the quality of a digital picture. A filter will be applied to the picture in order to enhance the quality of the image's edges.
- Detection: This stage extracts all edge points and then discards those found to be noise.
- Localization: This stage confirms the position of an edge (sub-pixel resolution is necessary for a few applications). An edge's position is more accurate than the gap between pixels).

1.2. Problem statement

Noise in images causes abrupt changes in pixel values, which may be seen in images. Edge detection based on Prewitt filtering and Sobel filtering will enhance the appearance of the object's boundary line in a picture. In this assignment we will use two edge detection algorithms namely Sobel and Prewitt edge detection techniques that are used in different images to extract edges and compare between efficiency of Prewitt filtering and Sobel filtering in edge detection of image.

1.3. Motivation

Investigate and compare the performance of two edge detectors: the Sobel operator and the Prewitt edge detector using multiple input pictures.

2. Literature review

Kalpana Saini and colleagues examined several edge detectors on echocardiographic pictures using the peak signal to noise ratio. Edge detection is used to determine the borders of homogenous sections in a picture based on their intensity and texture. They compared Prewitt, Robarts, LoG, Canny, and Sobel edge detectors and concluded that Sobel detector had a better PSNR than Prewitt detector [6]. According to a case study done by Ravi S in Operators Used in Edge Detection Computation, the Sobel operator is the most appropriate among first order derivative operators[7]. Furthermore, research by Deepika Adlakha and et al. compared the Sobel edge detection and Prewitt edge detection techniques. The Prewitt edge detection approach outperformed the Sobel edge detection technique in their tests, according to the researchers' conclusions[8]. Daniel Kim's study examines and analyzes the Sobel Operator and Canny Edge Detector. He finds that although the Sobel operator is straightforward, its accuracy degrades in noisy settings, while the Canny operator provides a smoothing effect that eliminates noise but is difficult to execute in real time[1]. Also, Rajshree Kumari and et al. conducted another comparative study of several edge detection techniques. Their article compared many edge detection approaches extensively used in image processing, including Canny, Prewitt, and Sobel. They discovered that the Sobel approach produces more precise edges and that Prewitt may be calculated fast [9]. Additionally, Abdel Karim M. Baareh and et al paper's Performance Evaluation of Edge Detection Using Sobel, Homogeneity, and Prewitt Algorithms They discovered that the Prewitt and Homogeneity algorithms performed better than the Sobel algorithm when compared utilizing the three methodologies. As a result, the Prewitt and Homogeneity algorithms may be

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suggested as effective edge identification techniques[10]. Ahmed Shihab Ahmed conducted a comparative analysis of three edge detection operators used in image processing in his work comparative study among Sobel, Prewitt, and canny edge detection operators used in image processing. The diagonal edge seems to be more sensitive to the Sobel operator than the horizontal and vertical edges. On the other hand, the Prewitt operator is more sensitive to horizontal and vertical edges [4]. Lili Han and colleagues describe an improved Sobel operator-based edge detection technique. Their experiments demonstrate that the enhanced edge detection technique improves picture positioning accuracy and has a limited capacity to attenuate noise. Finally, the picture edge recognized by the Sobel operator seems to be more sensitive and distinct than the classic Sobel operator [11]. Another paper by Rajni Nema and Dr. A. K. Saxena on Edge Detection Operators on Digital Images. Their study compares the performance of the Canny, Sobel, and Prewitt Edge Detectors in terms of object identification in frames. They discovered that the Prewitt filter had a significant disadvantage in terms of noise sensitivity when compared to other operators[12]. Additionally, S.K. Katiyar and P.V. Arun published a research titled Comparative examination of popular edge detection algorithms for object extraction. The analysis findings indicate that Canny's approach is the most suited for object extraction in most scenarios owing to its low false edge count, but Sobel is also a viable alternative due to its lower time and space difficulty [13].

2.1 Sobel Operator:

It was Sobel who first invented the Sobel edge detection technique in 1970. The Sobel technique of edge detection for picture segmentation discovers edges using the Sobel approximation to the derivative. When the gradient is steepest, it appears ahead of the edges. With the Sobel approach, a picture is given a 2-D spatial gradient quantity that emphasizes edge locations with a high spatial frequency. There are several applications for finding the approximate magnitude of an image's estimated absolute gradient at any given position. Conjecture suggests that at least two 3x3 complexity kernels are used by the operator, as shown below [3]:

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

G_x

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

G_y

Figure 2: *Soble X & Y Kernels*

2.2 Prewitt Operator:

Prewitt proposed the Prewitt edge detection in 1970. Prewitt is the right method for estimating the size and direction of an edge. While different gradient edge detection requires a lengthy computation to determine the direction from magnitudes in the x and y directions, compass edge detection derives the direction

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immediately from the kernel with the greatest response. It is restricted to eight potential directions; nonetheless, experience demonstrates that most direct direction estimations are not much more accurate. This gradient-based edge detector estimates eight directions in the 3x3 vicinity. Calculation of all eight convolution masks. Then, one complication mask is chosen, specifically for the biggest module's purpose[3].

-1	-1	-1
0	0	0
+1	+1	+1

G_x

-1	0	+1
-1	0	+1
-1	0	+1

G_y

Figure 3: *Prewitt X & Y Kernels*

3. Methodology

- The algorithm of Prewitt operator and Sobel Operator use two masks to find the edges: one for detecting edges in the horizontal direction and another for detecting edges in a vertical direction.
- At the beginning, a selected and fed into a computer program for processing. If the image is colored, it will immediately turn into a grayscale version.
- Then, different edge detection operators (Prewitt method and Sobel method) are applied to detect the object boundaries and edges.
- In conclude, compare between the different results.

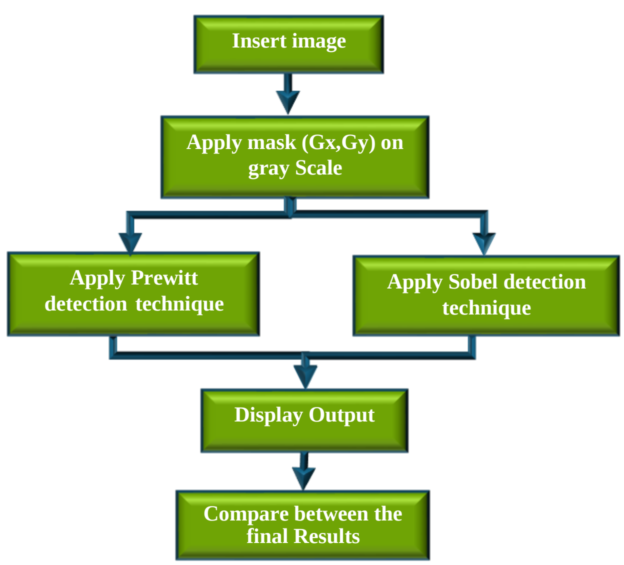

Figure 4: *Proposed model for Edge detection by Soble and Prewitt methods*

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3.1 Proposed Datase

We used Berkeley Segmentation Data Set 500 (BSDS500). It is a typical benchmark for contour detection. This dataset is meant for assessing natural edge detection that includes not only object outlines but also object inner borders and background boundaries. It comprises 500 natural photos with well labeled borders obtained from many users. We'll use 200 of the data for training, 100 for validation, and the remaining 200 for testing. There are three sections to the dataset [5].

3.2 Experiments

We conducted several experiments to compare various edge detectors on photos. We did the experiment using MATLABR2021a, using color pictures.

3.3 Experiments results

This section compares the performance of the Sobel edge detector with the Prewitt edge detector in terms of accuracy. The execution of this is done using a collection of colorful pictures. After converting colorful photos of flowers to gray scale, the resultant gray images are subjected to Sobel and Prewitt edge detection algorithms, which yields the image's edges. The following are a few examples of the images:

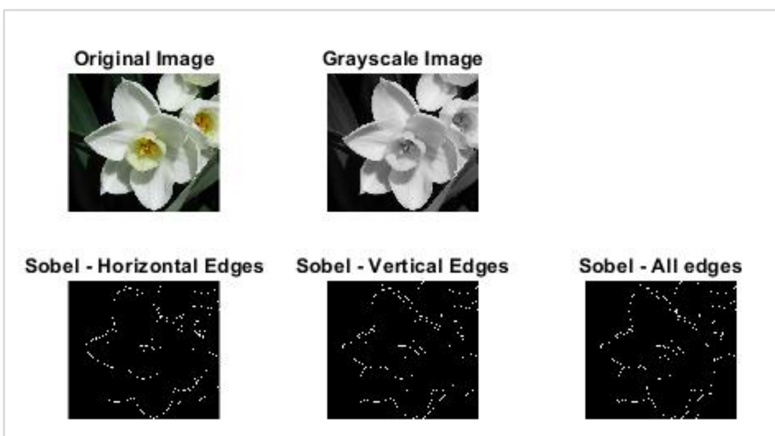

Figure 5: *Example1 for Sobel operator*

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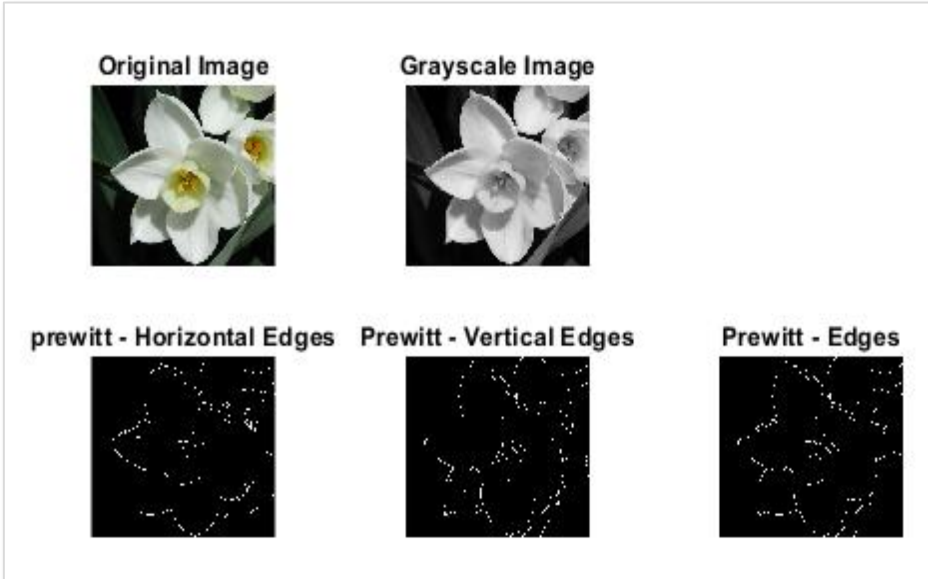

Figure 6: *Example 1 for Prewitt Operator*

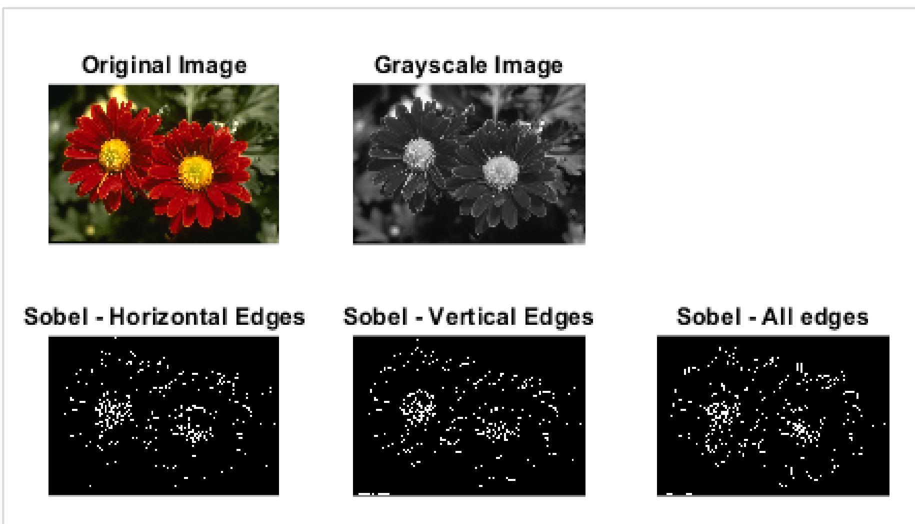

Figure 6: *Example2 for Sobel Operator*

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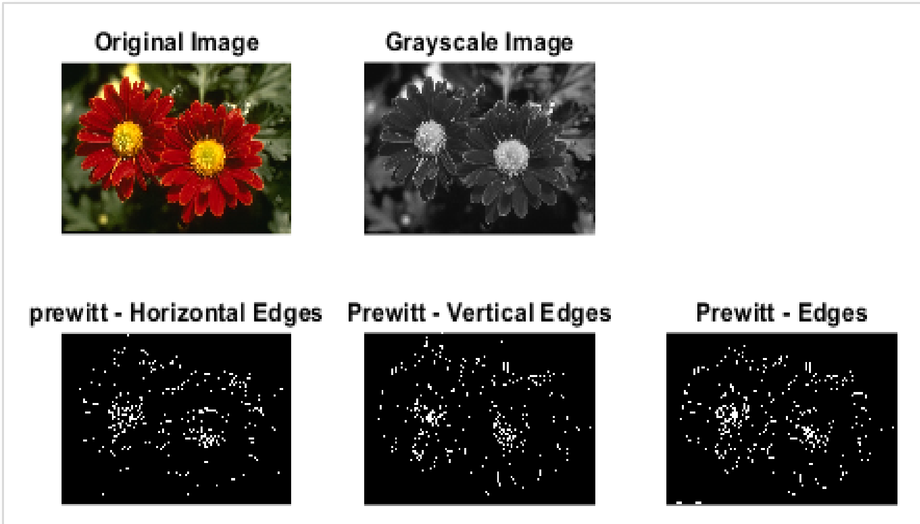

Figure 7: Example2 for Prewitt Operator

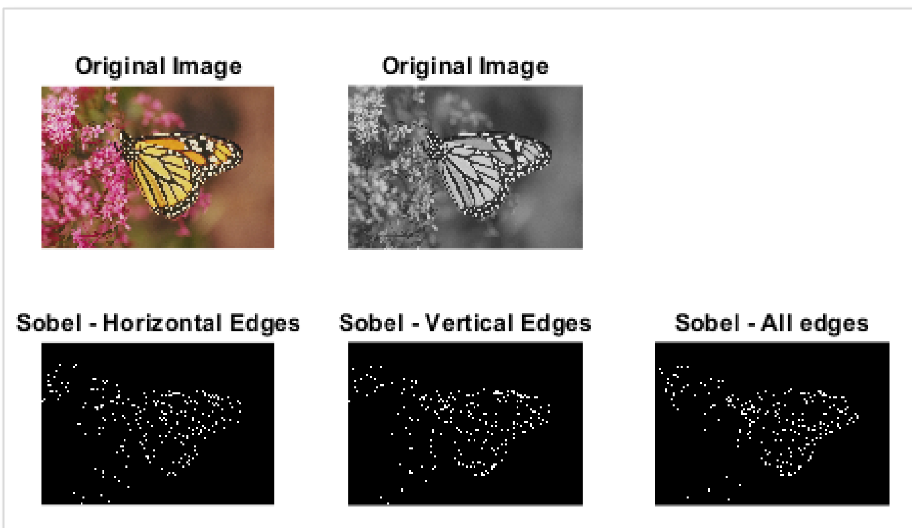

Figure 8: *Exampl3 for Sobel Operator*

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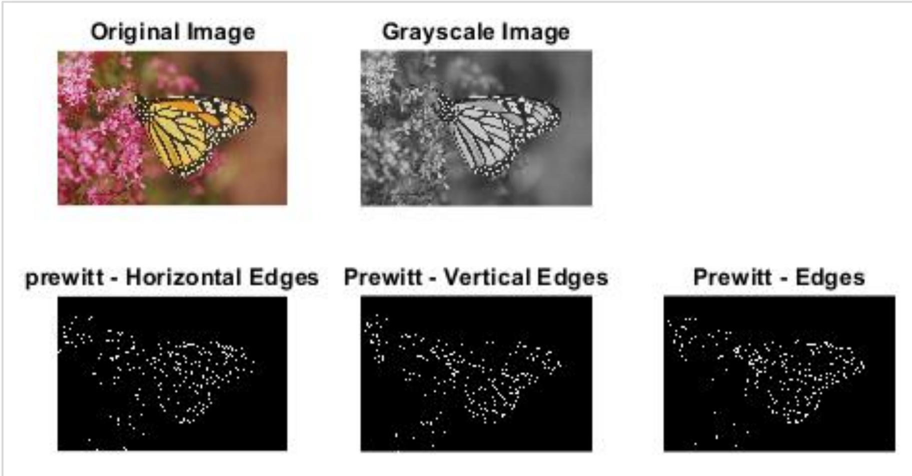

Figure 9: *Example3 for Prewitt Operator*

4. Results and Discussion

The comparison between the Sobel and Prewitt edge detection operators was conducted using multiple images from the Berkeley Segmentation Dataset (BSDS500). MATLAB was used for image preprocessing, algorithm implementation, and performance evaluation. The primary focus of the analysis was on edge clarity, computational efficiency, and the overall robustness of each method. The findings from the experiments are discussed below.

4.1 Edge Clarity and Precision

The Prewitt operator generally produced sharper and more precise edges compared to the Sobel operator. This was particularly evident in images with fine textures and intricate details. The smoother gradients captured by Prewitt enhanced boundary detection, leading to better-defined object outlines. However, in scenarios with high noise levels, the Prewitt operator showed a slight sensitivity to noise, occasionally introducing false edges.

4.2 Computational Efficiency

In terms of execution time, the Sobel operator was marginally faster than Prewitt in most experiments. The results in Table 1 illustrate that Sobel consistently required less time for processing, making it a preferred choice for applications where speed is critical, such as real-time image analysis. This difference, while not substantial, could be significant in time-sensitive environments.

Table 1: *The execution duration of each operator when it was employed to identify edges.*

Experiment	Method	Time(sec)
Experiment 1	Sobel	2.690 s
	Prewitt	1.142 s
Experiment 2	Sobel	1.141 s
	Prewitt	1.240 s
Experiment 3	Sobel	1.108 s
	Prewitt	1.174 s

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4.3 Robustness and Practical Applications

The robustness of the Sobel and Prewitt operators was also tested under varying image conditions. Sobel showed better stability in noisy environments, where the operator's smoothing effect helped reduce noise while preserving critical edges. This makes Sobel more reliable in environments with less controlled lighting or significant image artifacts. On the other hand, Prewitt excelled in controlled settings with high-quality images. Its ability to capture finer details without oversmoothing gave it an edge for applications where visual precision is paramount, such as medical imaging or digital photography.

4.4 Summary of Findings

- **Prewitt Operator**: Best suited for applications that require detailed edge detection and can tolerate longer processing times.
- **Sobel Operator**: Ideal for real-time applications and noisy environments due to its balance between speed and accuracy.

The results suggest that the choice between Sobel and Prewitt operators depends on the specific requirements of the application. Practitioners should carefully consider factors like image quality, computational resources, and desired precision when selecting an edge detection method.

5. Conclusion:

In this study, we compared the performance of the Sobel and Prewitt edge detection operators using various images and metrics such as accuracy and execution time. Through our experiments, it became clear that while both methods are effective in detecting edges, they each have their strengths. The Prewitt operator demonstrated superior clarity and produced more refined edges, particularly in images with complex textures. However, Sobel proved to be slightly faster, making it a practical choice for real-time applications where speed is crucial.

This comparison highlights that there is no one-size-fits-all solution when it comes to edge detection. The decision to use Sobel or Prewitt should depend on the specific requirements of the task at hand—whether it is accuracy, computational efficiency, or the type of image being processed. By understanding these differences, researchers and practitioners can make more informed choices that align with their project goals. Ultimately, this research contributes to the ongoing effort to improve image processing techniques and offers practical guidance for selecting the right edge detection method.

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