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COMPARATIVE STUDY AMONG SOBEL, PREWITT AND CANNY EDGE DETECTION OPERATORS USED IN IMAGE PROCESSING

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ABSTRACT

It is a fundamental process in image processing. The edges include a great deal of the information in the image. The edges give information about the locations of the objects, their shapes, their sizes and information concerning their texture.in this paper, three edge detection algorithms namely Sobel, Prewitt and Canny edge detection techniques that are used in different images to extract edges. Analyzing the Performance factors are done in the terms of time interval and accuracy on the premise of Mean Squared Error (MSE) and Peak signal to Noise Ratio (PSNR). C# is employed for edge detection. The experimental results shows that canny edge detection technique results higher than Prewitt and Sobel edge detection techniques.

Keywords: *Edge Detection, Image Processing, Sobel, Prewitt, Canny, PSNR, MSE.*

1. NTRODUCTION

Edge detection is that method of distinguishing and also locating sharp discontinuities within the image. It's employed by visual perception, target tracking, object detection etc. segmentation partition the image into a collection of disjoint regions that are uniform and significant and also regard to few characteristics to modify simple image analysis. Using Image processing in several applications for example video monitoring, medical imaging and traffic administration. Edge detection is that method that is used to locate an image edge. Edges are often classified primarily founded upon their intensity profiles for example roof edge, ramp edge, step edge and ridge edge. Edge detection are often tired four steps smoothing, improvements, detection and localization [1]. There are several edge detection algorithms, In edge detection, we tend to use two kinds of operators namely Laplacian-based and gradient-based edge detection. Edge detection target is to find the information about the shapes and therefore the reflectivity or transmission in an image and each detector is employed to detect edges and avoid false edges and should nearest to reference edges [2][3]. Edges are often classified based mostly upon their intensity profiles like step Edge, Ramp Edge, Ridge Edge, roof Edge as Shown in Figure 1.

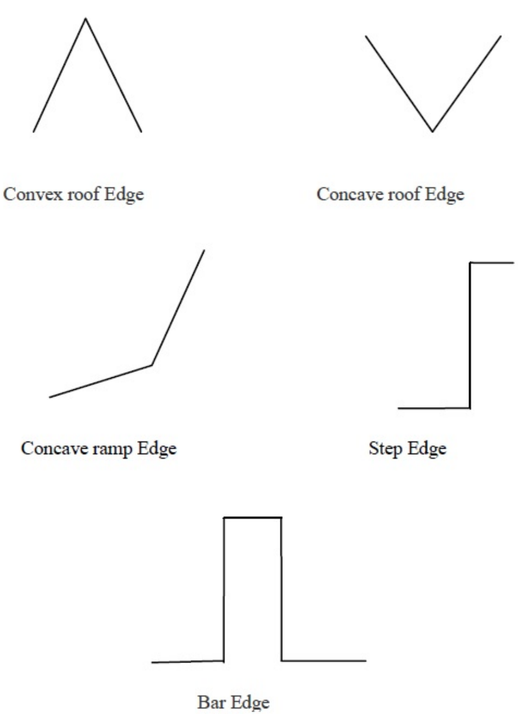

Figure 1: Different types of edges [4]

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The use of the electronic imaging and the fast growth within the range will provide the required image quality in several applications and justify attention for the systematic style of an image compression system [5]. It's one among the elemental steps in image analysis, image processing, and image pattern recognition. There are several applications of edge detection in an image processing which are computer vision, image segmentation, image compression, image encryption, medical diagnosis, image improvement etc. Improvement the standards of human viewing are samples of enhancement operators which is done by image improvement [6]. To compare the quality of image edge detection PSNR and MSE are employed. The edge detection operators are usually compared with common image, if the associate operator provides resultant image with high MSE, less PSNR, and less processing time then come to result that operator has high edge detection quality. There are four Steps in the edge detection as shown in Figure 2.

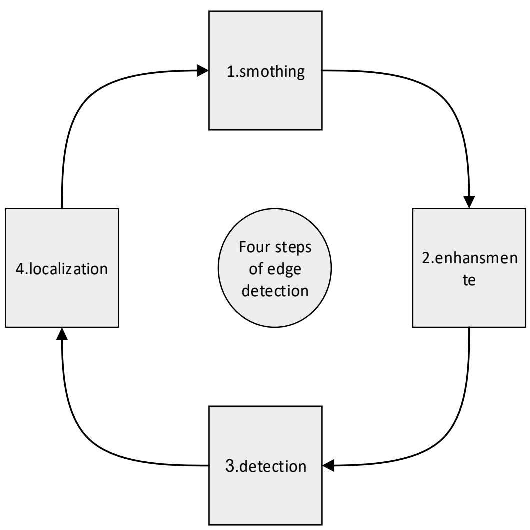

Figure 2: edge detection steps

● **Smoothing**: - This step contain filtering the image to reduce the noise and the performance of the edge detector will rise.
● **Enhancement**: - This step related with the digital image quality rising. Filter will be used to improve the image edges quality.
● **Detection**: - In this step all edge points will be extracted and then discard edge pixels that has been determined as noise.
● **Localization**: - Confirming the location of an edge is done in this step (For few applications sub-pixel resolution is required. The location of an edge is better estimated than the spacing between pixels).

This paper is divided as follow: Section 1 include introduction of the edge detection, edge detection methods various steps and its purpose. Section 2 contains different techniques of Edge detection. Then, Sobel, Prewitt and Canny edge detections are presented in Section 3. In Section 4 the experimental results and analysis by PSNR and MSE value are presented. The last Section include the paper followed by the references.

2. EDGE DETECTION APROGES

The algorithms of edge detection are classified founded on the behavioral study of edges with regard to the operators. Many various approaches of the Edge Detection are loosely classified beneath classical or gradient based edge detectors (first derivative), optimal edge-detector and Zero-crossing (second derivative) [7].
Several ways exist to carry out edge detection. But , the most of the various procedures may be classified into two classes specifically Laplacian and Gradient, see table 1.

Table 1: EDGE-DETECTION APPROACHES

METHODS	APPROACHES
1. First order derivative / Gradient method	Robert operator Sobel operator Prewitt operator
2. Second order derivative / Zero Crossing	Laplacian of Gaussian Difference of Gaussian
3. optimal edge detection	Canny edge detection

1. Gradient: - The edges are detected by the gradient methodology which is one by searching for the minimum and the maximum within the initial derivative of the image.
2. Laplacian: - The methodology of Laplacian seeks in the second derivative of the image for zero crossings to seek out edges. An Edge contain 1D form of a ramp and the location of the image can be highlighted by calculating it's derivative.
There are several classical operators such as Robert, Sobel and Prewitt but are sensitive to noise. Several detection methods exist within the domain of an image edge detection but each one has a certain problems. The foundation step in computer vision is edge detection, to get the best

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results it is important to point out true edges from the process of matching. So that is the reason why it's necessary to decide on edge detectors that match the best system [8].

3. METHODOLOGY

Ineffective knowledge, noise, and frequencies are filtered out in edge detection while keeping the necessary structural properties in the image. One of the favored ways to represent input images and its features is edge maps [4]. First of all Sobel, Prewitt and Canny algorithms are applied to 5 images and by using C# software to search for the results. Secondly, the value of PSNR and MSE is calculated between every input image and the resultant edge detected image. This research paper contains, Sobel, Prewitt, and Canny edge detection algorithms are compared to find the superior edge detection algorithm.

A. Mean Squared Error

The average of the squares of the "errors" is measured by the mean squared error of an estimator i.e. the difference between the estimator and what is estimated. The contrast happen due to randomness or as a result of the estimator doesn't calculate information that could result in a better accurate estimate. The PSNR differ inversely with the MSE. The M.S.E can be found from the following Equation 1:

$$MSE = \frac{1}{MN\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(I(i,j)-K(i,j)\right)^2} \quad (1)$$

Where I (i, j) and K (i, j) are the edge detected image and ground truth image respectively and M, N are the dimensions of the image.

B. Peak signal to noise ratio

The ratio between the power of corrupting noise and the most possible power of a signal that influences the sincerity of its representation is PSNR. Here, PSNR cites the ratio between the edge detected images i.e. the estimator output and the ground truth image which is also said to be the estimated image. PSNR can be rated by the following Equation 2:

$$PSNR = 20.log10\left(\frac{max_i}{\sqrt{MSE}}\right) \quad (2)$$

MAX_i is the maximal variation in the input image data. If it has an 8-bit unsigned integer data type, MAX_i is 255.

3.1 Sobel Edge Detection

Edge detection could be a method that locates the image edge necessary in calculating the approximate absolute gradient magnitude in every point of an input gray-scale image. The issue of computing a suitable absolute gradient magnitude for edges lies in the utilized approach [9]. The Sobel performs a two-dimensional spatial gradient measure on images. Which transfers a two-dimensional pixel array to statistically uncorrelated dataset to eliminate repeated data, thus, reducing the data amount is necessary for representing a digital image. This edge detector utilizes a pair of 3×3 convolution masks, one to estimate gradients in the x-orientation and the other one to estimates gradients in the y–orientation. Sobel detector is of a high sensitivity to noise in pictures, it efficiently highlights them as edges. Therefore, this operator is recommended in huge data communications that are detected in data transferring. Sobel masks are given as in Figure 3 [9]:

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

G_x

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

G_y

Figure 3: 3x3 Sobel edge detection masks

Each one of those masks is convolved with the image. At every pixel locations there are a couple of number: S1, S2 correspond to the output form the mask of row and column subsequently. Those numbers are utilized for computing 2 matrices, the edge magnitude and orientation, by applying the following Equation 3 and Equation 4:

$$\text{Edge Magnitude} = \sqrt{S1^2 + S2^2} \quad (3)$$

$$\text{Edge Direction} = \tan^{-1}\frac{S1}{S2} \quad (4)$$

Algorithm 1: Applying Sobel edge detector on gray scale image
Input: gray scale image
Output: Sobel edge detected sketch

input(Sobel Mask G_x in figure 3)
input(Sobel Mask G_y in figure 3)
For i=0 to Image width -1
  For j=0 to Image height -1
    For m=0 to 2

```
  For n=0 to 2
  S1=image(I+m,j+n)* Sobel Gx Mask (m,n)
  S2=image(I+m,j+n)* Sobel Gy Mask (m,n)
  End for
End for
Edge Magnitude = squrt (S1^2+S2^2)
 sketch Image(I+1,j+1)= Edge Magnitude
end for
end for
End
```

3.2 Prewitt Edge Detection

This operator is like Sobel but with different coefficients of the mask. The derivatives should have the following properties [10]:

- Mask should contain opposite signs.
- Sum of the mask have to be equal to zero.
- More edge detection due to more weight.

The masks are defined as following Figure 4.

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

G_x

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

G_y

Figure 4: 3x3 prewitt edge detection masks

Each of these masks is convolved with the image. At each pixel location there are two numbers: P1, P2 that correspond to the output from the row, column masks subsequently. Those results are utilized for determining two measurements, the edge magnitude and its orientation as defined in the following Equation 5 and Equation 6, [10]:

$$\text{Edge Magnitude} = \sqrt{P1^2 + P2^2} \quad (5)$$

$$\text{Edge Direction} = \tan^{-1}\frac{P1}{P2} \quad (6)$$

Algorithm 2: Applying Prewitt edge detector on gray scale image.

Input: gray scale image

Output: **Prewitt edge detected sketch**

```
input(Prewitt Gx Mask in Figure 4 )
input(Prewitt Gy Mask in Figure 4 )
For i=0 to Image width -1
 For j=0 to Image height -1
sum=0
  For m=0 to 2
  For n=0 to 2
  p1=image(I+m,j+n)* Prewitt Gx Mask(m,n)
  p2=image(I+m,j+n)* Prewitt Gy Mask(m,n)
  End for
End for
Edge Magnitude =squrt(p1^2+p2^2)
 Sketch image(I+1,j+1)= Edge Magnitude
end for
end for
End
```

3.3 Canny Edge Detection

Although many edge detection algorithms have been developed, one of the foremost strictly defined methods that provide good and reliable detection is the Canny edge detection algorithm. Due to its simplicity of process for implementation and optimality to satisfy the three criteria for edge detection, it's now very popular edge detection algorithm. Canny's approach is based on three basic objectives, [11].

Discovering the optimal edge detection algorithm was the goal of Canny. During this scenario, an "optimal" edge detector means:

Good detection – as possible mark several real edges in the image by the algorithm.

Good localization – edges marked ought to be as close as possible to the edge in the real image.

Minimal response – marking the given edge in the image only once , and where possible , no false edges should be created by the noise in an image.

The steps of applying canny edge detection will be describe as follows: [12]:

- Smoothing: - it's certain that each image taken by a camera can have some volume of noise. It's important to not mistaken a noise for an edge, for that noise should be reduced. Therefore Gaussian filter is used to smooth the image first. The result of the Gaussian smoothing is shown in the previous section.

$$k=\frac{1}{159}\cdot\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} \quad (7)$$

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- Finding Intensity Gradients: - The aim of the Canny algorithm is to find edges where the grayscale intensity of the image alters the most. When determining the gradients of the image those areas could be found. The Sobel-operator is used to determine the gradients at each pixel in the smoothed image. In the first step, the kernels shown up top in the previous section in figure 3 are used to approximate the gradient in the x- and y-direction respectively. The law of Pythagoras is used to determine the gradient magnitudes (The edge strengths) can then be determined as a Euclidean distance measure as shown in Equation 3.
- Non-Maximum Suppression: - The aim of this stage is to transform the "blurred" image edges of the gradient magnitudes to "sharpen" the edges. Essentially this is performed via maintaining all local maxima in the gradient image, and eliminating everything else. The algorithm is for every pixel in the gradient image is:

  1. Round the gradient orientation θ to nearest 45° that correspond to using an 8-connected neighbors.

  2. Perform a comparison of the edge intensity of the pixel to the edge intensity of the pixels in the positive and negative gradient orientations. In other words, in the case where the gradient orientation is north (ɵ is equal to 90°), compare to the pixels to the north and to the south.

  3. In the case where the edge intensity of the pixel is biggest; maintain the value of the edge intensity. Otherwise, remove that value. Nearly all pixels of gradient orientations point to the north. Thus, they are compared to pixels above and below. The pixels which happen to be maximal in this comparison are marked with white borders. The rest of the pixels will be eliminated [11].
- Double Thresholding: - The edge-pixels that remain after the step of the non-maximum suppression are marked by their power (i.e. pixel-by-pixel). Several of those possibly be actual edges in the image, however, some of them might be a result of noise or color changes for example, because of rough surfaces. The simplest method of discerning between those by using a threshold, in order to ensure that only edges which are greater than a specific value would be maintained. Canny algorithm implements dual thresholding. Edge pixels which are robust than the high threshold are marked as powerful; edge pixels which are softer than the low threshold are discarded and edge pixels between the two thresholds are marked to be weak.
- Hysteresis Edge Tracking: - The detection of edges is completed by suppressing all the other edges that are soft and not connected to strong edges. But, there is some talk on the weak edge pixels as these pixels can either be extracted from the noise/color variations or the true edge. To reach an accurate result the weak edges caused by the latter reasons would be taken away.

  This approach is one of the classic edge detection methods. It was proposed by J. Canny for his M.Sc. thesis at MIT in the year of 1983, and this operator is still more efficient that has more versions. For finding edges via the separation of noise from the image be for finding edges of image the Canny is an approach of a higher importance. This approach is a more efficient approach without disturbing the edge properties in the image after it applies the tendency for finding edges and the serious value for threshold.

Algorithm 3: applying Canny Edge Detector on gray scale image.
Input: gray scale image
Output: **canny edge detected sketch**
Begin **Step1:** Smoothing using Gaussian filter mask, See Equation 8. **Step2** : Finding intensity gradients by applying sobel edge detect. See algorithm 1. **Step3**: applying Non-maximum suppression to convert blurring edge to sharp edge. **Step4**: Double thresholding to discern between edges if they are true edge or caused by noise or color variations. **Step5**: Edge tracking by hysteresis to chack the weak edges if connected to strong edge they will remain and if they are not, they will be removed. **End**

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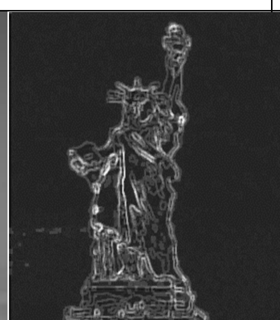
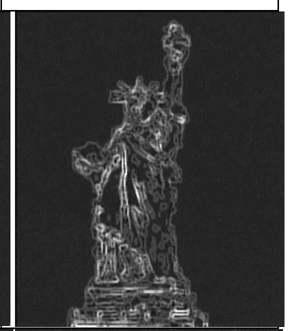
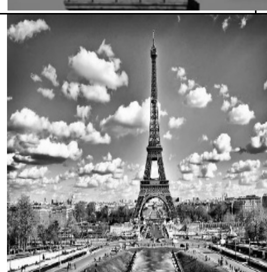
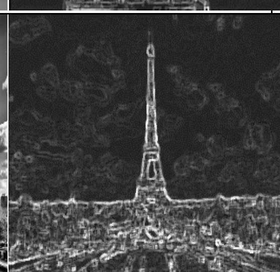
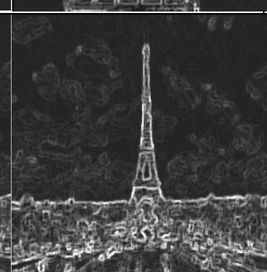
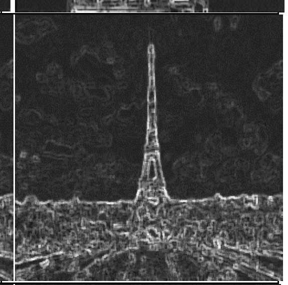
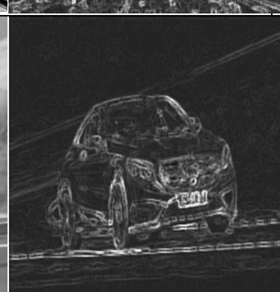
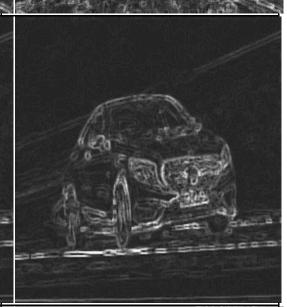
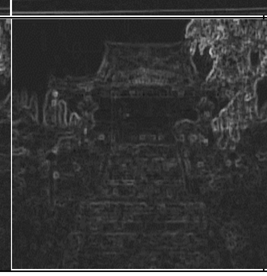
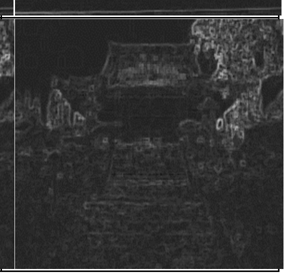
4. EXPERIMENTATIONS

Three different edge detection algorithms Sobel, Prewitt and Canny have been compared in this experiment. The comparison is done by computing the execution time of each algorithm. Also MSE and PSNR of each image with respective to their corresponding ground truth images. The images that have been taken for analysis are Statue of liberty, Evil Tower, car, Japanese House and Saint Basil's Cathedral. Table 2 shows the test image and the output images generated by each algorithm. Table 3,4,5,6 and 7 shows the computed MSE, PSNR for execution of the five algorithms on the images Statue of liberty, Evil Tower, car, Japanese House and Saint Basil's Cathedral respectively and finally table 8 shows the execution time to for each algorithm to find the edge detection for all five test images together. Nots that the execution time measured be detecting all the test images together and record the time it take for each algorithm to find the edge detection.

Table 2: the results of applying three edge detection operators on five original gray scale images

Image name	**Gray scale image**	**Sobel operator**	**Prewitt operator**	**Canny operator**
Statue of liberty				
Evil Tower				
Car				
Japanese House				

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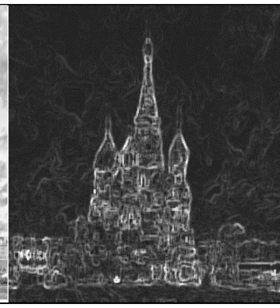
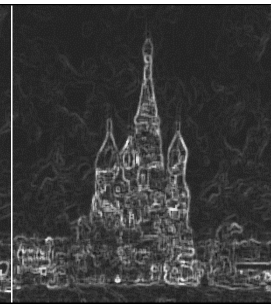
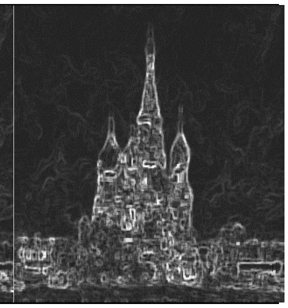
Saint Basil's Cathedral				

Table 3: Results produced by applying edge detection operators on the gray scale Statue of liberty image

Statue of liberty	Sobel operator	Prewitt operator	Canny operator
MSE	17759.2559161677	17768.8534850299	17834.2861317365
PSNR	5.63655595273984	5.63420954513852	5.61824630723252

Table 4: Results produced by applying edge detection operators on the gray scale Evil Tower image

Evil Tower	Sobel operator	Prewitt operator	Canny operator
MSE	12551.4797873393	12542.5808456973	12558.3958902077
PSNR	7.14385429824546	7.14693451827712	7.1414619125351

Table 5: Results produced by applying edge detection operators on the gray scale Car image

Car	Sobel operator	Prewitt operator	Canny operator
MSE	13806.5754350196	13814.6063547176	13927.7695647786
PSNR	6.72994390769285	6.72741846599793	6.69198788109942

Table 6: Results produced by applying edge detection operators on the gray scale Japanese House image

Japanese House	Sobel operator	Prewitt operator	Canny operator
MSE	15155.7021859329	15177.7135226667	15515.6001702931
PSNR	6.32504298197175	6.31874009550982	6.22311781359893

Table 7: Results produced by applying edge detection operators on the gray scale S B's Cathedral Image

Saint Basil's Cathedral	Sobel operator	Prewitt operator	Canny operator
MSE	5109.65077661431	5104.3772600349	5330.12527923211
PSNR	11.0468914194105	11.0513759564529	10.8634294406652

Table 8: execution time for each algorithm when it's used to find edge detection for all five images together

Algorithms	Time(in sec)
Sobel	34.9
Prewitt	34.85
Canny	34.3

5. RESULTS AND DISCUSSION

It can be observed from the numerical results that the sobel and prewitt operator shows the highest average PSNR. On the other hand, canny operator shows the least average PSNR among the three tested algorithms. It is important to note that an edge detector operator with the least PSNR have the highest edge detection capabilities and Canny appears to have the least maximum average MSE and least average PSNR. It can be noticed that in less complex images, the canny algorithm shows high PSNR. This is because canny operator is capable of detecting weak edges and thus, it has a higher chance of detecting false edges. When talking about time complexity, noticing the average processing time, Prewitt operator gives so much better performance than the others. On the other hand, canny operator takes consumes maximum time among other operators. Tables above shows MSE and PSNR respectively for the three algorithms under test. The Sobel operator has a higher sensitivity to the diagonal edge than to the horizontal and vertical edges. As opposite, Prewitt operator has a higher degree of sensitivity to horizontal and vertical edges. Also canny operator find edges by detaching noise from the image before finding images edges, Canny is a significant operator, Because it never disturb the features of the edges in the image. Applying the tendency to search out the edges and also the serious threshold value. Not like Sobel or Prewitt the Canny operator isn't terribly prone to noise. In the case of Canny detector if it worked well it would be superior.

6. CONCLUSION

This paper mentioned three different edge detection. The measurements that used to evaluate the three edge detection are Mean Square Error, Processing Time needed for 5 different images to detect edges and Peak Signal to Noise Ratio. In edge detection C# software is used. In this research paper the performance of Sobel, Prewitt and Canny edge detection techniques are applied. Eventually it appears that the algorithm of Canny edge detection produce the highest accuracy in edge detection techniques and takes lower execution time than sobel and prewitt. It should also be noticed that sobel operator has a higher sensitivity to the diagonal edge than to the horizontal and vertical edges. As opposite, Prewitt operator has a higher degree of sensitivity to horizontal and vertical edges.

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