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Influence of Salt and Pepper Noise on the Edge Detection of Images Using Modified Canny Edge Detector with S-Membership Function

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Abstract: *Edges in a digital image provide important information about the objects contained within the image since they constitute boundaries between objects in the image. The extraction of these features can be further used for real time purposes like face recognition, computer vision algorithms etc. But it is somewhat difficult to extract out all the edges efficiently without affecting the structural properties of an image. Edges in an image represent a swift change in the intensity even in the presence of noise. It is essential to study the edge detecting properties of an image when the noise in the image is abundant. Edge detection in noisy images is in agreement between denoising and edge preserving capability. Various smoothing filters are appropriately studied in the viewpoint of edge detection. This paper describes the influence of various intensity levels of noise in the edge detection of images and detailed statistical metrics for understanding the efficiency of the proposed method. In this work, two images such as butterfly and fruit are considered and salt and pepper noise is added to these images at various levels of intensity (5% to 50%). In the next stage a median filter is utilized to denoise the images and the edges are analyzed with the help of modified canny method using S-membership function. The statistical metrics of shows that the edges of the resultant image is strictly preserved till 25% of noise intensity levels. The severe degradation of edges is observed in the image for the noise intensity levels more than 25% of salt & pepper noise.*
Key Word*: Image, Edge Detection, Noise, Filter, Canny, Ground truth image*

I. Introduction

In this Digital era Digital image processing is becoming very important to retrieve the useful information from the image. Image processing is a process that is used to perform operations like filtering, and transforming on the image, that is the simplest definition of image processing. Image-processing has a lot of advantages. These advantages expand into many areas like engineering, medical science, agriculture, industry and military. A picture is worth a thousand words". Just like words, the clearer the pictures, the better they are understood. The correct understanding of the image message in the world of medicine (e.g., MRI images) or self-driving cars can be crucial for humans. The approach that a system/computer applies to learn about a process (message) or represented components (features of the picture) is based on breaking down the input data and reconstructing the output data as similar as possible to the input.

Edge represents the abrupt change in the intensity of the pixels, which leads to discontinuity in the brightness or contrast. Usually, edges occur on the boundary of two regions of an image. Edge Detection is a fundamental image processing technique which involves computing an image gradient to quantify the magnitude and direction of edges in an image. Image gradients are used in various downstream tasks in computer vision such as line detection, feature detection, and image classification [1]. This edge detection is used in many areas like research, medical field, and Artificial intelligence etc.

Image noise is random variation of brightness or color information in images and is usually an aspect of electronic noise. It can be produced by the image sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. An edge in an image represents a swift change in the intensity of an image and noise in an image also signifies the same so what happens when noise is abundant in an image. Hence there is a need of removing the noise, for that we use different filters like gaussian, bilateral, median etc., There are different techniques used for this finding edges-Roberts, Sobel, Canny, Prewitt, Laplacian of Gaussian, and Zero Cross [2].

The Canny edge detector is an edge detection operator that uses a multi stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986. Canny also produced a computational theory of edge detection explaining why the technique works. Among the edge detection methods developed so far, Canny edge detection algorithm is one of the most strictly defined methods that provides good and reliable detection [3]. Owing to its optimality to meet with the three criteria for edge detection and the simplicity of process for implementation, it became one of the most popular algorithms for edge detection.

The traditional Canny operator has two most obvious problems when detecting image edges. First, the filter part adopts the Gaussian filter, and the parameters of the Gaussian filter are not easy to set, and it lacks adaptability in the process of image edge detection. To solve this problem, many scholars have made improvements like replacing the Gaussian filter with the median filter. Second, when the influence of noise is large, false edges will be detected, and the edges will be lost in small parts where the gray level change is not obvious [4].

II. Proposed Methodology

Noise Models and Denoising

Noise is unwanted information in a digital image which produces and desirable effects such as unseen lines, corners and blurred objects. To reduce this kind of effects prior learning noise models is essential. Generally, noise may arise with various sorts of sources like sensors, environmental issues etc. Probability density function or a histogram function is not used to design the characteristics of noise models[5].

Salt & Pepper Noise: The salt and pepper noise are also called shot noise, impulse noise or spike noise that is usually caused by faulty memory locations, malfunctioning pixel elements in the camera sensors, or there can be timing errors in the process of digitization. In the salt and pepper noise there are only two possible values exists that is ‘a’ and ‘b’ and the probability of each is less than 0.2[6]. If the numbers greater than this numbers the noise will swamp out image. For 8-bit image the typical value for 255 for salt-noise and pepper noise is 0 as shown below eq. (1) [7].

$$p(z) = \begin{cases} p_a \; for \; z = a \\ p_b \; for \; z = b \\ 0 \; Otherwise \end{cases} \qquad (1)$$

The intensity of noise levels decides the efficiency of Edge detection, Since Edge and Noise represents the same. Different Noises exhibits different behaviour.

Filtering image data is a standard process used in almost every image processing system. They remove noise from images by preserving the details of the same. The choice of filter depends on the filter behavior and type of data. It is well known that noise is abrupt change in pixel values in an image. So, when the type of filter is median it considers a specific mask as 3*3, 5*5 or 7*7 etc, the main intension of usage of this filter is to eliminate blurriness in the image under certain conditions it also preserves the edges of the image by eliminating the noise[8].

Fuzzy S-Membership Function

Membership functions characterize fuzziness (i.e., all the information in fuzzy set), whether the elements in fuzzy sets are discrete or continuous. Membership functions can be defined as a technique to solve practical problems by experience rather than knowledge, Membership functions are represented by graphical forms, Rules for defining fuzziness are fuzzy too[9]. There are so many membership functions are existed in neural networks and fuzzy logic among them S-member function is one of the functions which is used to determine hypothesis of canny to find out more edges in the given input image[10]. The shape of S-function is commonly used to represent brightness of given input image pixels. Originally S function is introduced by Zadeh for flexibility the evaluation criteria of S function is represented in eq. 2,

$$S(x;a,b,c)=\begin{cases} 0, & x\le a \\ \frac{(x-a)^2}{(b-a)(c-a)}, & a<x\le b \\ 1-\frac{(x-c)^2}{(c-b)(c-a)}, & b<x\le c \\ 1, & x\ge c \end{cases} \qquad (2)$$

Where a, b and c are parameters determining the shape. The definition of b can be median, a and c are two random values generated as mean-variance and mean + variance.

A few categories of noises are available in digital image processing among them salt & pepper considered for the evaluation of their impact in the edge detection in this work. In the proposed method various percentage levels of additive noise is applied to an image. The experimental results are extracted to visualize the details of the edges with respect to canny edge detection as well as modified canny edge detection with S-membership function. Both the methods are compared with original ground truth image and their impact is noticed with the help of various parameters like True Positive, True Negative, False Positive, False Negative, False alarm etc, at various proportionate levels. How effectively the median filter removes the 30% noise level of salt & pepper noise of fruit image without much damaging the information about original image is as shown in Fig. 1.

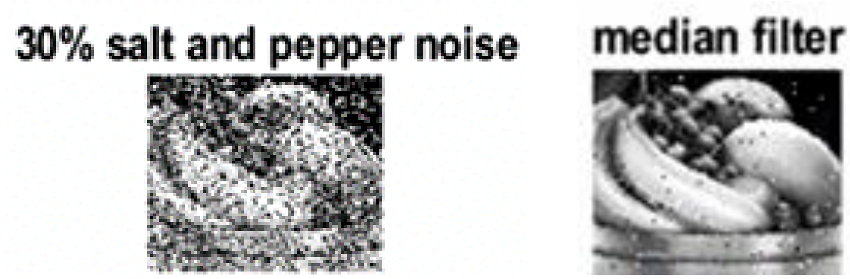


Fig 1: Applying filter to noisy image

The Process of work flow step by step is demonstrated with the flow chart in Fig.2 Further experimental results are implemented for the two images with different intensities of noise.

III. Experimental Results and Discussion

The two images like butterfly and fruit have been chosen for analysis. The salt & pepper noise at different noise levels from 05 to 50% is added to the gray scale images. To analyze the efficiency of the edge detecting methods, various statistical metrics such as True positive values (TP values), true negative values (TN values), etc is evaluated[11]. The detailed description of these parameters is available in our earlier work.

The following image shown in Fig. 3 realizes the efficiency of edge detection of fruit image with the salt and pepper noise is added in various proportions ranging from 0% to 25%. The edge preservation is realized using the modified canny with fuzzy membership. The edges of the output image obtained from modified canny for fruit image shows that when the noise level increases the edge preservation decreases, the noise ranging from 5% to 25% have the clear edges.

The Fig. 4 shows the fruit images with 30% to 50% Salt & Pepper Noise which realizes that on increasing the noise intensity the Edge preservation is decreasing. Table 1 provides the comparison of different statistical parameter values for the fruit image with different noise intensities for salt and pepper noise. Butterfly image is chosen as second set of image which is added with salt & pepper noise of varied intensity levels from 0% to 50%. The butterfly image with noise, the output of the median filter and the edge detection of the image is shown in Fig. 5. Table 2 describes the statistical measures of butterfly image influenced by the salt & pepper noise at various levels. The variation of different parametric values of fruit and butterfly image is shown in Fig. 6. The variation reveals that for both the images (butterfly and fruit) the robustness of the filter is applicable to 25% of the noise intensity levels. Beyond 25% of noise intensity levels, the median filter shows its inability to detect the edges.

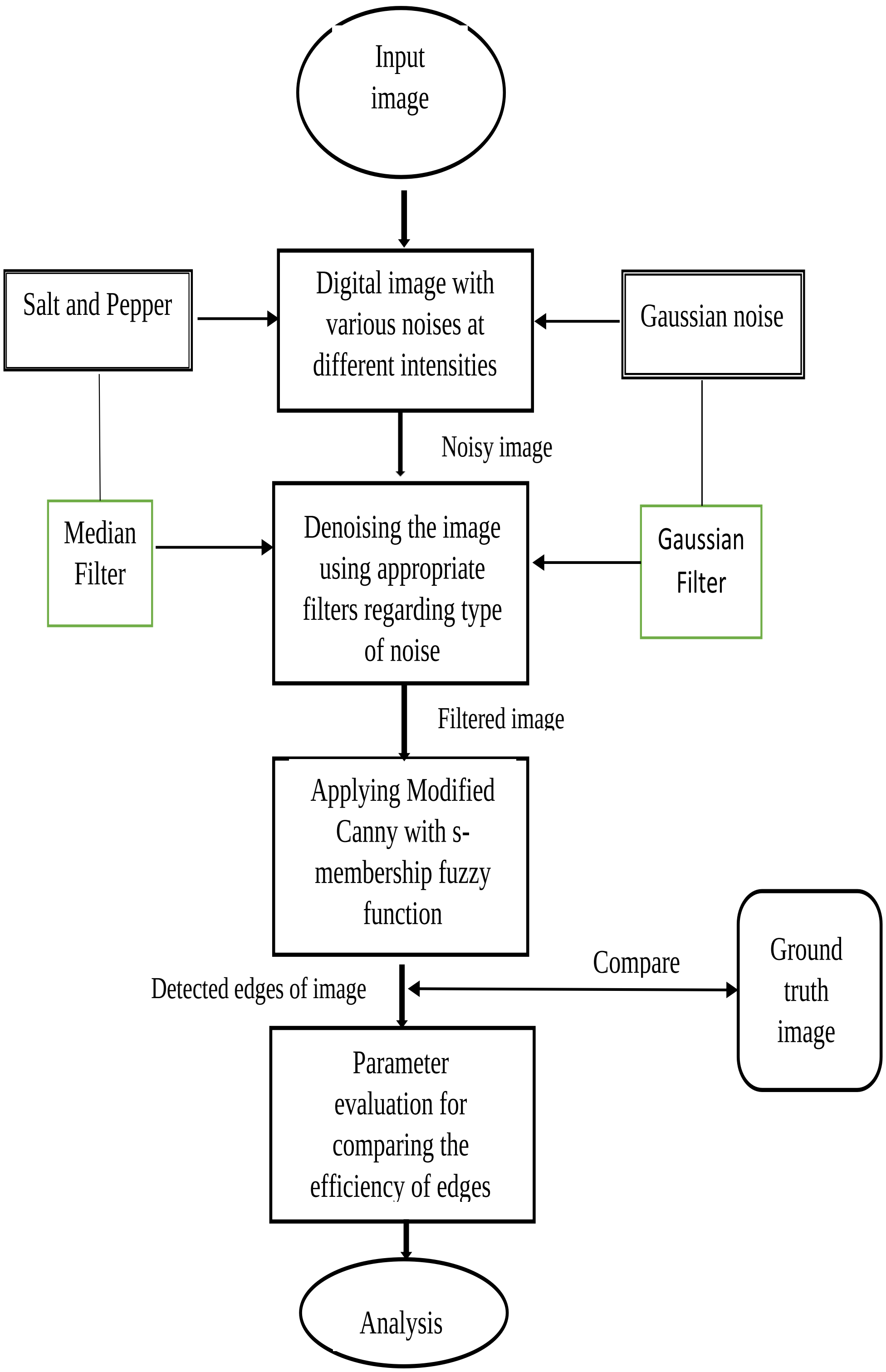


Fig 2: Flow chart for Detecting edges and analysis

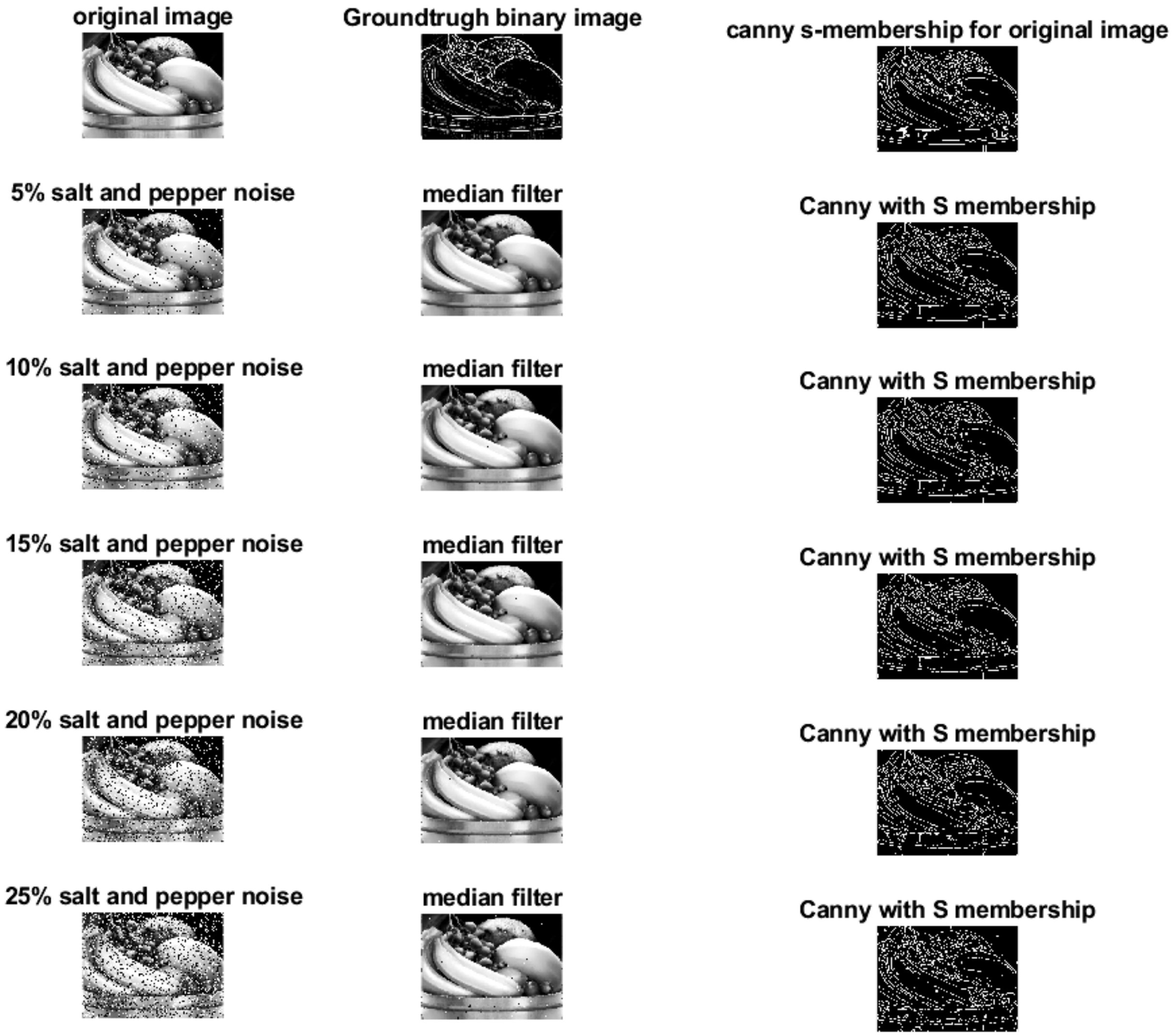
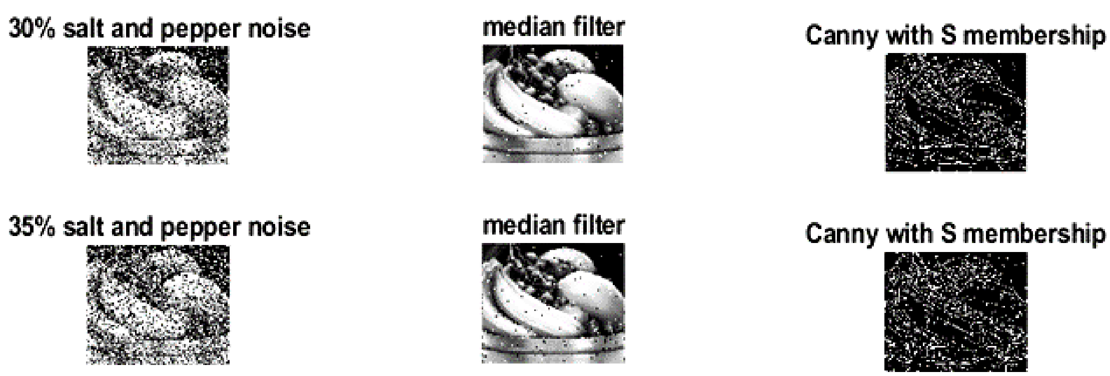


Fig 3: Output images of edge detection at 0% to 25% intensities of salt& Pepper noise



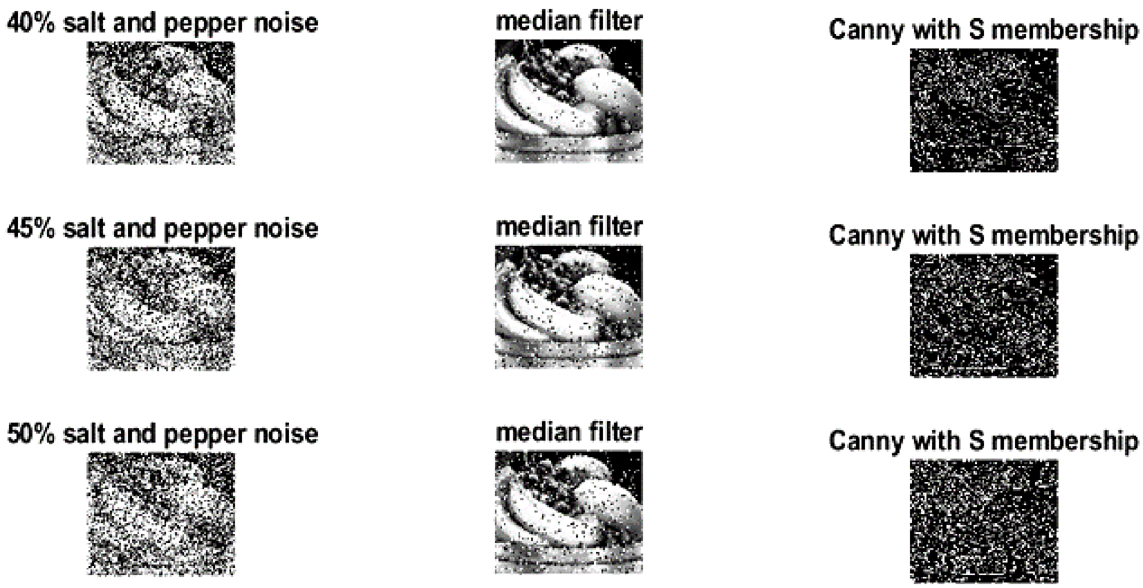


Fig. 4: Output images of edge detection at 30% to 50% intensities of salt& Pepper noise

	TPV	FPV	TNV	FNV	PCO	PND	PFA	IMP	D^4
Ideal value (0%)	0.00	0.00	37562.00	0.00	0.00	0.00	0.00	100.00	99.00
S-Canny	2061.00	4891.00	32671.00	10623.00	0.1624	0.8375	0.3856	79.5078	78.5177
5%	1825.00	4226.00	33336.00	10859.00	0.1438	0.8561	0.3478	76.5473	75.5577
10%	1903.00	4436.00	33126.00	10781.00	0.1500	0.8499	0.3497	77.4361	76.4464
15%	1975.00	4355.00	33207.00	10709.00	0.1500	0.8442	0.3433	78.7177	77.7277
20%	2019.00	4550.00	33012.00	10665.00	0.1591	0.8408	0.3587	78.8028	77.8127
25%	2049.00	4825.00	32737.00	10635.00	0.1591	0.8384	0.3804	78.8028	77.8128
30%	2227.00	5284.00	32278.00	10457.00	0.1755	0.8244	0.4165	80.9872	79.9968
35%	2425.00	5743.00	31819.00	10259.00	0.1911	0.8088	0.4527	82.8913	81.9005
40%	2686.00	6531.00	31031.00	9998.00	0.1911	0.7882	0.5149	87.2910	86.3000
45%	2921.00	7619.00	29943.00	9763.00	0.2302	0.7697	0.6006	88.7635	87.7723
50%	3263.00	8386.00	2917.00	9421.00	0.2310	0.7427	0.6611	88.7635	87.7725

Table 1: Statistical metrics of Fruit Image with varied noise intensity levels of Salt & Pepper Noise

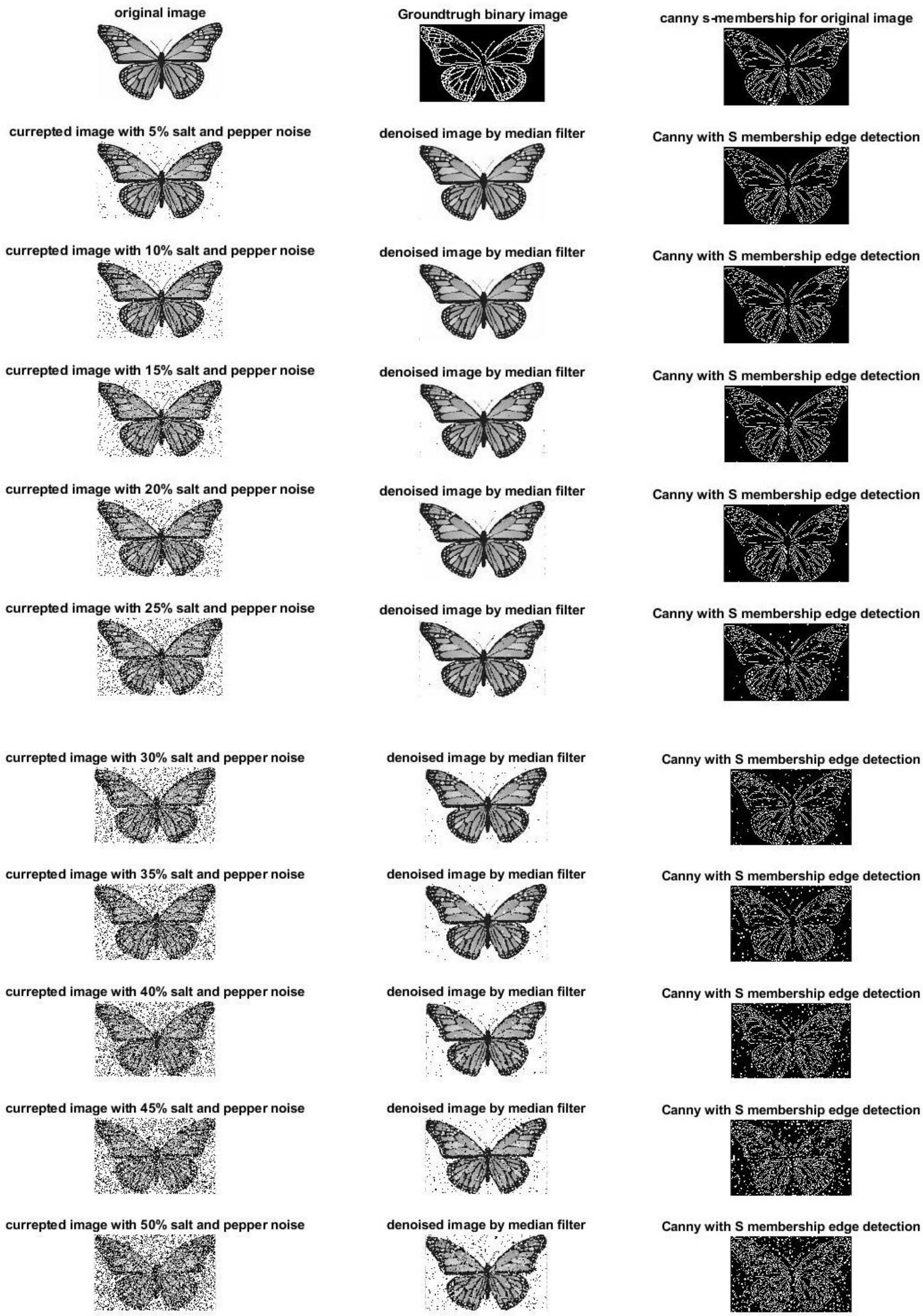
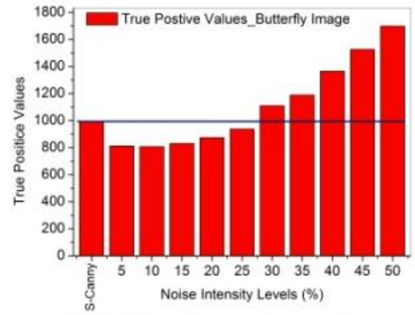
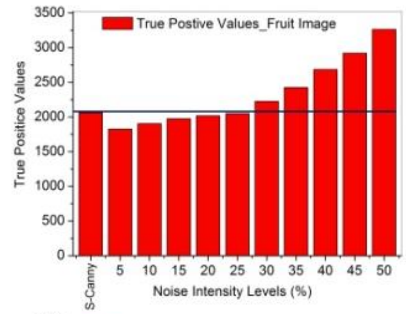
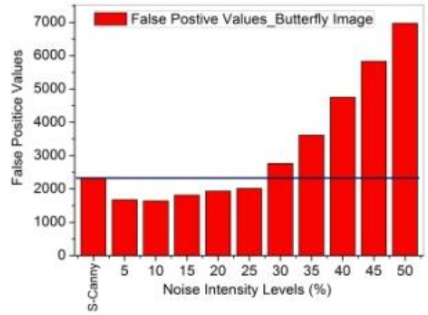
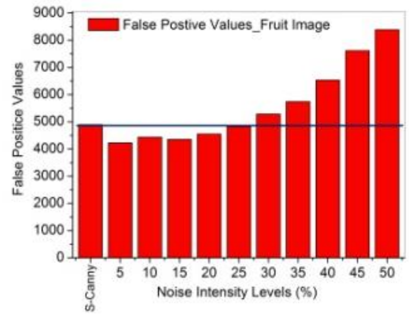


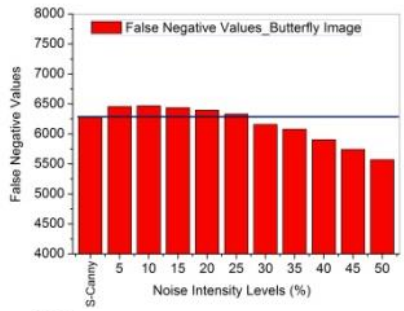
Fig. 5. Edge detection of butterfly image with varying salt & pepper noise intensity levels from 0% to 50%

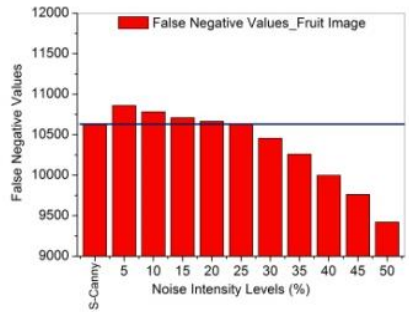

True Postive Values_Butterfly Image
True Positice Values
S-Canny
Noise Intensity Levels (%)

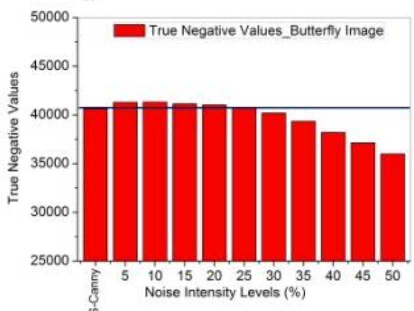

True Postive Values_Fruit Image
True Positice Values
S-Canny
Noise Intensity Levels (%)

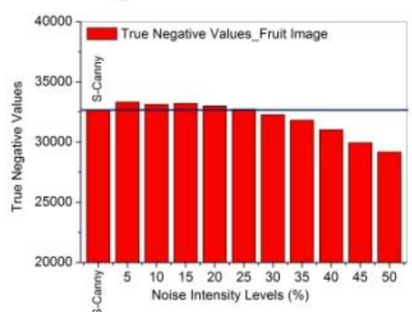

False Postive Values_Butterfly Image
False Positice Values
S-Canny
Noise Intensity Levels (%)

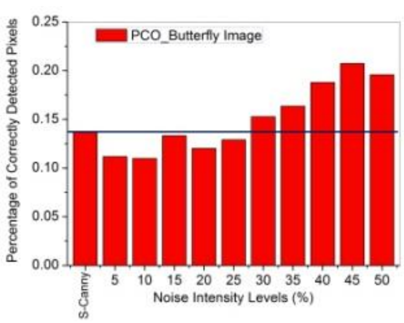

False Postive Values_Fruit Image
False Positice Values
S-Canny
Noise Intensity Levels (%)

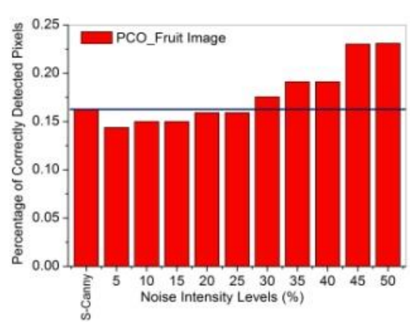

False Negative Values_Butterfly Image
False Negative Values
S-Canny
Noise Intensity Levels (%)


False Negative Values_Fruit Image
False Negative Values
S-Canny
Noise Intensity Levels (%)


True Negative Values_Butterfly Image
True Negative Values
S-Canny
Noise Intensity Levels (%)


True Negative Values_Fruit Image
True Negative Values
S-Canny
Noise Intensity Levels (%)


PCO_Butterfly Image
Percentage of Correctly Detected Pixels
S-Canny
Noise Intensity Levels (%)


PCO_Fruit Image
Percentage of Correctly Detected Pixels
S-Canny
Noise Intensity Levels (%)

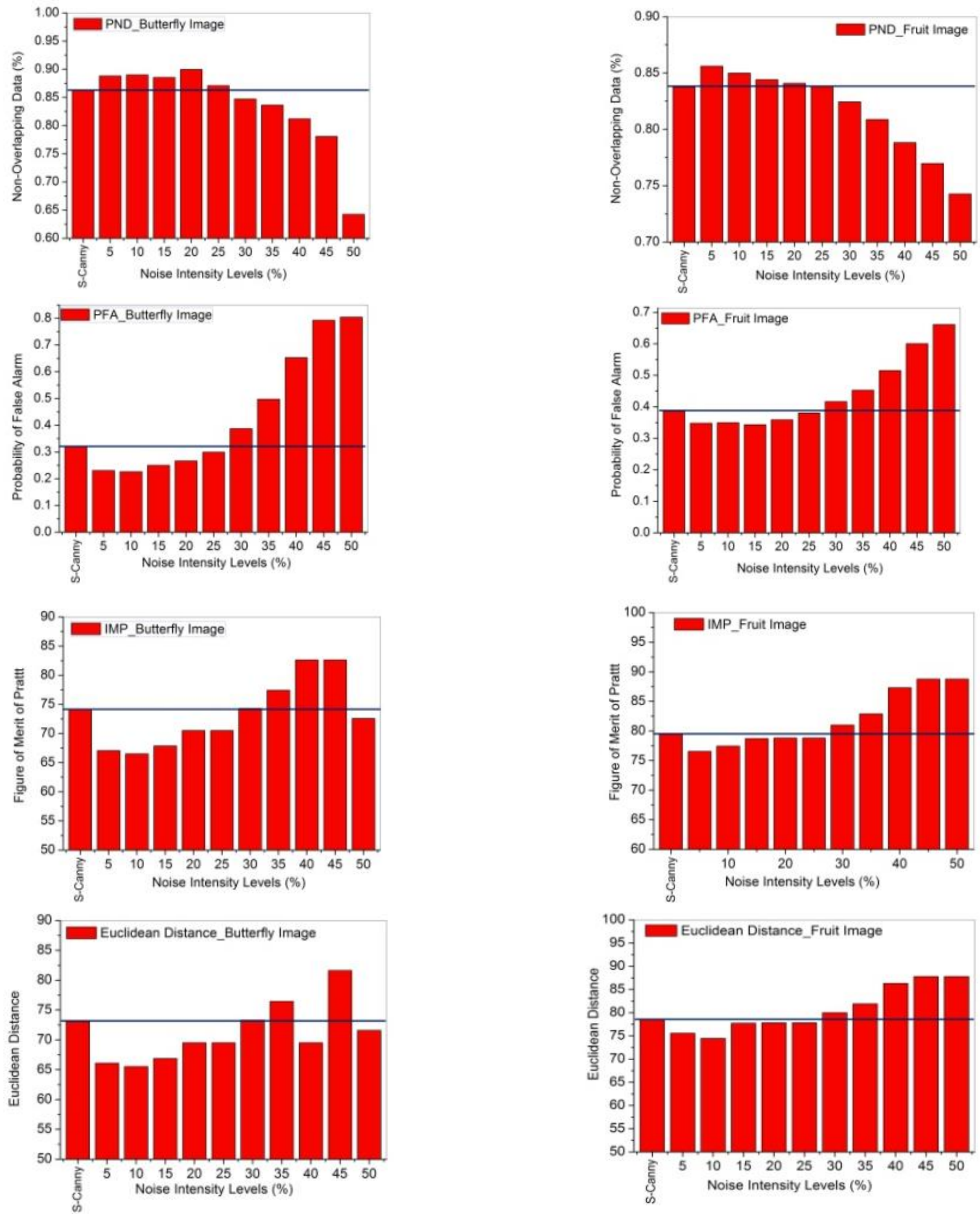


Fig 6. Variations of statistical metrics of images (butterfly and fruit) for different noise (salt & pepper) intensity levels with modified canny as reference.

	TPV	FPV	TNV	FNV	PCO	PND	PFA	IMP	D^4
Ideal value (0%)	0.00	0.00	42967.00	0.00	0.00	0.00	0.00	100.00	99.00
S-Canny	993.00	2332.00	40635.00	6275.00	0.1366	0.8633	0.3208	74.0555	73.0664
5%	812.00	1676.00	41291.00	6456.00	0.1117	0.8882	0.2306	67.0658	66.0781
10%	807.000	1644.00	41323.00	6469.00	0.1099	08900	0.2261	66.5180	65.5305
15%	831.00	1817.00	41154.00	6437.00	0.1333	0.8856	0.2500	67.8594	66.8717
20%	874.00	1937.00	41030.00	6394.00	0.1202	0.8997	0.2665	70.4963	69.5079
25%	938.00	20176.00	40791.00	6330.00	0.1290	0.8709	0.2993	70.4963	69.5078
30%	1110.00	2766.00	40201.00	6158.00	0.1527	0.8472	0.3875	74.2935	73.3043
35%	1189.00	3615.00	39352.00	6079.00	0.1635	0.8364	0.4973	77.4271	76.4378
40%	1365.00	4752.00	38215.00	5903.00	0.1878	0.8121	0.6528	82.6043	69.5078
45%	1526.00	5829.00	37138.00	5742.00	0.2074	0.7806	0.7925	82.6043	81.6157
50%	1698.00	6970.00	35997.00	5570.00	0.1958	0.6425	0.8041	72.5668	71.5787

Table 2: Statistical metrics of Butterfly Image with varied noise intensity levels of Salt & Pepper Noise

IV. Conclusion

Edge detection deals with feature extraction of the image. Since the edge and noise depicts the same in image the edge detection of noisy image demands for the improved procedure. To deal with this in the proposed method the preprocessing of image i.e., denoising image with appropriate filter is introduced before performing the edge detection. In the proposed method two noises namely salt & pepper and Gaussian are considered. For salt and pepper noise the levels are varied in range 0% to 50% by considering as multiples of five and denoised using the median filter then the modified canny with s-membership is used to detect the edges. The output images reveal that up to 30% the edges extracted were clear but on increasing the noise level, that will degrade efficiency of edge preservation. Various metrics are calculated in order to analyze the efficiency of edge preservation under different noises with various proportions. The results show that under various noise levels the efficiency of edge detection using modified canny with s-membership is quit decent in certain ranges of noise levels.

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