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ALGORITHMS FOR EDGE DETECTION BY USING FUZZY LOGIC TECHNIQUE

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ABSTRACT

The fuzzy technique is an operator introduced in order to simulate at a mathematical level the compensatory behavior in process of decision making or subjective evaluation. This paper introduces such operators on hand of computer vision application. novel method based on fuzzy logic reasoning strategy is proposed for edge detection in digital images without determining the threshold value. The proposed approach begins by segmenting the images into regions using 3x3 binary matrix. The edge pixels are mapped to a range of values distinct from each other. The robustness of the proposed method results for different captured images are compared to those obtained with the linear Sobel Robert and Canny operators. It is gave a permanent effect in the lines smoothness and straightness for the straight lines and good roundness for the curved lines. In the same time the corners get sharper and can be defined easily.

Keywords: *Fuzzy logic, Edge detection, Image processing, computer vision, Mechanical parts, Measurement.*

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خوارزميات كشف الحافات باستخدام تقنية المنطق المضبب

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الملخص

أن تقنية المنطق المضبب هي عبارة عن تقديم وادخال مؤثرات يتم من خلالها محاكات المعادلات الرياضية اللازمة في عمليات صنع القرار او المقارنة والتقييم للمواضيع. وفي هذا البحث عمل على تقديم هذا الموثرات للمساعدة في تطوير التطبيقات الصورية والمرئية للحاسوب. وقد أستند في هذا البحث على اسلوب حل العقدة بالمنطق المضبب لكشف الحافات في الصور الرقمية بدون وضع قيمة حرجة كقيمة عتبة . ان التقريب المقترح تم من خلال البدء بتقسيم الصورة الى مناطق 3x3 لمصفوفة ثنائية. وقد رسمت نقاط الحافات الى مدى من القيم والتي كانت منفصلة عن بعضها البعض. القوة في هذه الطريقة أدت الى الحصول على نتائج يمكن مقارنتها مع طريقة المؤثرات الخطية لمؤثرات Sobel Robert and Canny . وقد اعطت تأثيرا دائميا في نعومة الخطوط وقوتها واستقامتها وكذلك كانت الانحنائات جيدة للمنحنات المائلة. في نفس الوقت كانت الزوايا حادة ويمكن التعرف عليها بسهولة.

الكلمات الدالة : كشف الحافات ، معالجة الصور ، الرؤيا الحاسوبية ، الاجزاء الميكانيكية ، القياسات، المنطق الضبابي.

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1.INTRODUCTION

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Classical methods of edge detection involve convolving the image with an operator (a 2-D filter), which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. There is an extremely large number of edge detection operators available, each designed to be sensitive to certain types of edges [1].

2.EDGE DETECTION TECHNIQUES

Sobel Operator:

The operator consists of a pair of 3×3 convolution kernels as shown in Figure.(1) . One kernel is simply the other rotated by 90°.

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

Gx

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

Gy

Figure.(1): Horizontal and vertical Sobel operator

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *x*-direction and *y*-direction)[2]. These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by[2]:

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$$|G| = \sqrt{Gx^2 + Gy^2}$$ -----------(1)

Typically, an approximate magnitude is computed using[3]:

$$|G| = |Gx| + |Gy|$$ ------------ (2)

which is much faster to compute.

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by[4]:

$$\theta = \arctan(Gy/Gx)$$

Prewitt's Operator:

Prewitt operator is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images as shown in Figure.(2) [3,4].

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

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

Figure.(2): Horizontal and vertical Prewitt's operator

Canny's Edge Detection Algorithm

The Canny edge detection algorithm is known to many as the optimal edge detector. Canny's intentions were to enhance the many edge detectors already out at the time he started his work. He was very successful in achieving his goal and his ideas and methods can be found in his paper[5]. In his paper, he followed a list of criteria to improve current methods of edge detection.

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The first and most obvious is low error rate. It is important that edges occurring in images should not be missed and that there be NO responses to non-edges. The second criterion is that the edge points be well localized. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be at a minimum. A third criterion is to have only one response to a single edge. This was implemented because the first 2 were not substantial enough to completely eliminate the possibility of multiple responses to an edge[5],[6],[7]. Based on these criteria, the canny edge detector first smoothes the image to eliminate and noise. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (nonmaximum suppression). The gradient array is now further reduced by hysteresis[7]. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a nonedge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the 2 thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above T2 [8].

Step1

In order to implement the canny edge detector algorithm, a series of steps must be followed. The first step is to filter out any noise in the original image before trying to locate and detect any edges. And because the Gaussian filter can be computed using a simple mask, it is used exclusively in the Canny algorithm. Once a suitable mask has been calculated, the Gaussian smoothing can be performed using standard convolution methods. A convolution mask is usually much smaller than the actual image. As a result, the mask is slid over the image, manipulating a square of pixels at a time. The larger the width of the Gaussian mask, the lower is the detector's sensitivity to noise. The localization error in the detected edges also increases slightly as the Gaussian width is increased. The Gaussian mask used in my implementation is shown in Figure (3) .

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$$\frac{1}{115}$$

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

Figure.(3): Discrete approximation to Gaussian

Step 2

After smoothing the image and eliminating the noise, the next step is to find the edge strength by taking the gradient of the image. The Sobel operator performs a 2-D spatial gradient measurement on an image. Then, the approximate absolute gradient magnitude (edge strength) at each point can be found. The Sobel operator uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows) shown in Figure.(1) equation (3) for finding the edge direction. The magnitude, or edge strength, of the gradient is then approximated using equation (2)

Step 3

The direction of the edge is computed using the gradient in the x and y directions. However, an error will be generated when sumX is equal to zero. So in the code there has to be a restriction set whenever this takes place. Whenever the gradient in the x direction is equal to zero, the edge direction has to be equal to 90 degrees or 0 degrees, depending on what the value of the gradient in the y-direction is equal to. If G has a value of zero, the edge direction will equal 0 degrees. Otherwise the edge direction will equal 90 degrees. The formula for finding the edge direction is just:

Theta = invtan (Gy / Gx)

Step 4

Once the edge direction is known, the next step is to relate the edge direction to a direction that can be traced in an image. So if the pixels of a 5x5 image are aligned as follows:

x	x	x	x	x
x	x	x	x	x
x	x	a	x	x
x	x	x	x	x
x	x	x	x	x

Then, it can be seen by looking at pixel "a", there are only four possible directions when describing the surrounding pixels - 0 degrees (in the horizontal direction), 45 degrees (along the positive diagonal), 90 degrees (in the vertical direction), or 135 degrees (along the negative diagonal). the edge orientation has to be resolved into one of these four directions depending on which direction it is closest to (e.g. if the orientation angle is found to be 3 degrees, make it zero degrees). Think of this as taking a semicircle and dividing it into 5 regions as in Figure.(4) .

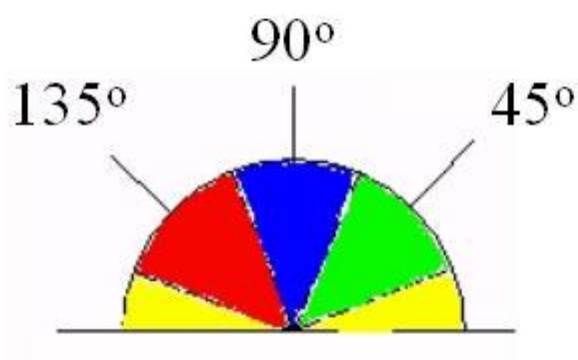

Figure.(4): Directions when describing the surrounding pixels.

Step 5

After the edge directions are known, nonmaximum suppression now has to be applied. Nonmaximum suppression is used to trace along the edge in the edge direction and suppress any pixel value (sets it equal to 0) that is not considered to be an edge. This will give a thin line in the output image.

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Step 6

Finally, hysteresis is used as a means of eliminating streaking. Streaking is the breaking up of an edge contour caused by the operator output fluctuating above and below the threshold. If a single threshold, T1 is applied to an image, and an edge has an average strength equal to T1, then due to noise, there will be instances where the edge dips below the threshold. Equally it will also extend above the threshold making an edge look like a dashed line. To avoid this, hysteresis uses 2 thresholds, high and low. Any pixel in the image that has a value greater than T1 is presumed to be an edge pixel, and is marked as such immediately. Then, any pixels that are connected to this edge pixel and that have a value greater than T2 are also selected as edge pixels. If you think of following an edge, you need a gradient of T2 to start but you don't stop till you hit a gradient below T1.

The Canny Edge Detection Algorithm

The algorithm runs in 5 separate steps:

1. Smoothing: Blurring of the image to remove noise.

2. Finding gradients: The edges should be marked where the gradients of the image has large magnitudes.

3. Non-maximum suppression: Only local maxima should be marked as edges.

4. Double thresholding: Potential edges are determined by thresholding.

5. Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

Each step is described in the previous subsections.

The Sobel and Prewitt’s Operators Edge Detection Algorithm

Step1: Create a binary image: for all x,y

If F (x,y) $\leq$t then f(x,y) =1

Step2: Create mask, w, with 3x3,a=(m-1)/2 and b=(n-1)/2.

Step3: Create an MxN output image, g:For all x and y. Set g(x,y)=f(x,y).

Step4: Checking for edge pixels:

For all y∊ {b+1…… N-b}, and x∊{a+1 …… ,M-a},

Sum=0;

For all k∊{-b,…..,b},and j∊{-a,…….,a},

If(f(x,y)=F(x+j,y+k)) Then sum=sum+1.

If (sum >6) Then g(x,y)=0 Else g(x,y)=1

Edge Detection by using Median Filter Modification

An algorithm to determine the median of pixels in the neighborhood of a pixel under interest is now presented. The median of the pixels is utilized to modify the pixels[13]. This median is computed separately for each color component in the following steps:

Step1: Take a window of size *w*×*w* centered on the pixel of interest in the corrupted image.

Step2: Arrange all the pixels of the window as a vector. Sort the vector in an increasing order and compute the median of the sorted vector.

Step3: Calculate the difference between each window pixel and the median of the vector.

Step4: Arrange all the window pixels

Step5: Sort the new vector and obtain the median *med* of the sorted vector.

Step6: Apply the last result to obtain the output image

Fuzzy Image Processing

Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification as shown in Figure.(5) . The fuzzification and defuzzification steps are due to the fact that do not possess fuzzy hardware. Therefore, the fuzzification of image data and defuzzification of the results are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values).After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach.

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Fuzzy Sets and Fuzzy Membership Functions

The functions adopted to implement the "and" and "or" operations were the minimum and maximum functions, respectively. The method was chosen as the defuzzification procedure, which means that the fuzzy sets obtained by applying each inference rule to the input data were joined through the add function; the output of the system was then computed as the lo m of the resulting membership function. The values of the three membership's function of the output are designed to separate the values of the blacks, whites and edges of the image Figure.(5) .The system implementation was carried out considering that the input image and the output image obtained after defuzzification are both 8-bit quantized; this way, their gray levels are always between 0 and 255. The fuzzy sets were created to represent each variable's intensities; these sets were associated to the linguistic variables "Black"edge. In the system described in [10, 11], all inputs to the fuzzy inference systems (FIS) system are obtained by applying to the original image a high-pass filter, a first order edge detector filter (Sobel operator) and a low-pass (mean) filter as in Figure.(6) . The whole structure is then tuned to function as a contrast enhancing filter and, in another problem, to segment images in a specified number of input classes. The adopted fuzzy rules and the fuzzy membership functions are specified according to the kind of filtering to be executed. In this paper a novel FIS method based on fuzzy logic reasoning strategy is proposed for edge detection in digital images without determining the threshold value or need training algorithm. The proposed approach begins by segmenting the images into regions using floating 3x3 binary matrix Figure.(5) . A direct fuzzy inference system mapped a range of values distinct from each other in the floating matrix to detect edge.

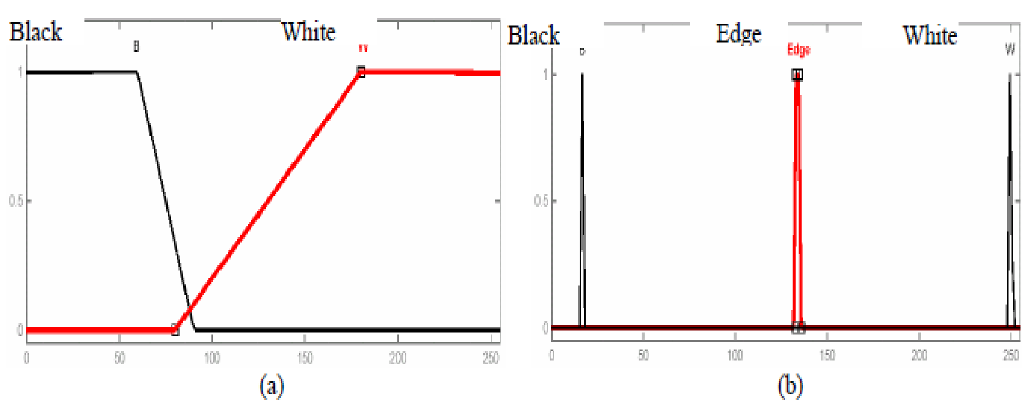

Figure. (5): Membership functions of the fuzzy sets associated to the input and to the output

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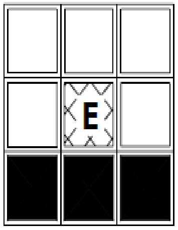
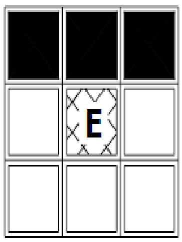
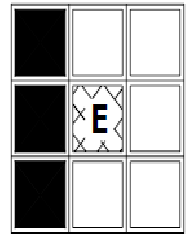


Rule1

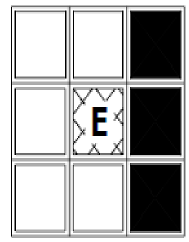


Rule2

Rule1	If {(i-1, j-1) & (i-1, j) & (i-1, j+1) } are whites If {(i, j-1) & (i, j) & (i, j+1) } are whites If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are blacks	checked pixel is **Edge**
Rule2	If {(i-1, j-1) & (i-1, j) & (i-1, j+1) } are blacks If {(i, j-1) & (i, j) & (i, j+1) } are whites If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are whites	checked pixel is **Edge**
Rule3	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) } are blacks If {(i-1, j) & (i, j) & (i+1, j) } are whites If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are whites	checked pixel is **Edge**
Rule4	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) } are whites If {(i-1, j) & (i, j) & (i+1, j) } are whites If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are blacks	checked pixel is **Edge**

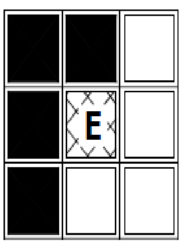


Rule3

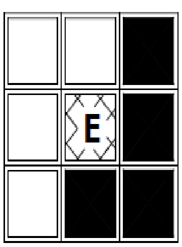


Rule4

(a)

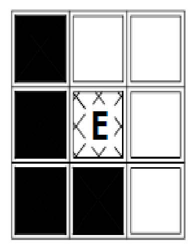


Rule5

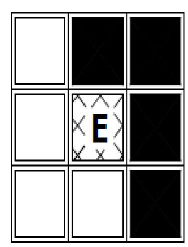


Rule6

Rule5	If {(i-1, j) & (i-1, j-1) & (i, j-1) & (i+1, j-1)} are blacks If {(i-1, j+1) & [i, j+1] & (i+1, j+1) &(i+1, j)} are whites If (i, j) is white	checked pixel is **Edge**
Rule6	If {(i-1, j) & (i-1, j-1) & (i, j-1) & (i+1, j-1)} are whites If {(i-1, j+1) & [i, j+1] & (i+1, j+1) & (i+1, j)} are blacks If (i, j) is white	checked pixel is **Edge**
Rule7	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) & (i+1, j)} are blacks If {(i-1, j) & (i-1, j+1) & (i, j+1) & (i+1, j+1)} are whites If (i, j) is white	checked pixel is **Edge**
Rule8	If {(i-1, j) & (i-1, j+1) & (i, j+1) & (i+1, j+1)} are blacks If {(i-1, j-1) & (i, j-1) & (i+1, j-1) & (i+1, j)} are whites If (i, j) is white	checked pixel is **Edge**



Rule7



Rule8

Figure.(6): The Fuzzy System rules

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[i-1, j-1]	[i-1, j]	[i-1, j+1]
[i, j-1]	[i, j]	[i, j+1]
[i+1, j-1]	[i+1, j]	[i+1, j+1]

Floating mask 3x3

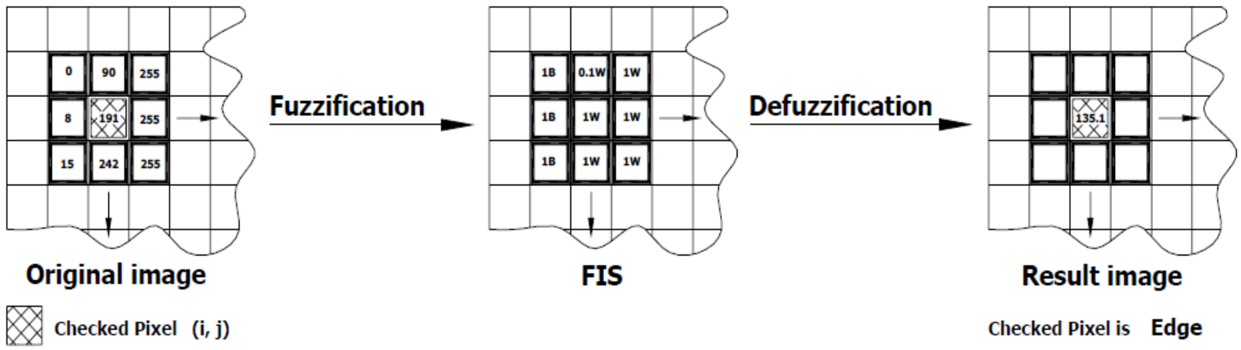

Figure.(7): Steps of fuzzy image processing.

Edge detection in Figure.(6) of all four types was performed for image on Figure.(7) Fuzzy yielded the best results. This was expected as Canny edge detection accounts for regions in an image. Canny yields thin lines for its edges by using non-maximal suppression. Canny also utilizes hysteresis when thresholding. Motion blur was applied to Figure.(6) . Then, the edge detection methods previously used were utilized again on this new image to study their affects in blurry image environments. No method appeared to be useful for real world applications. However, Canny produced the best the results out of the set.

3.RESULTS AND DISCUSSION

In this paper, the algorithm to find the edges associated with an image had been introduced which has been instrumental to abridge the concepts of artificial intelligence and digital image processing. Comparisons were made amongst the various other edge detection algorithms that have already been developed and displayed the accuracy of the edge detection using the fuzzy relative pixel value algorithm over the other algorithms which has tremendous scope of application in various areas of digital image processing. The image edge detection using fuzzy relative pixel value algorithm has been successful in obtaining the edges that are present in an image after the implementation and execution of the algorithms with various sets of images as in Figures.(8,9,10) .

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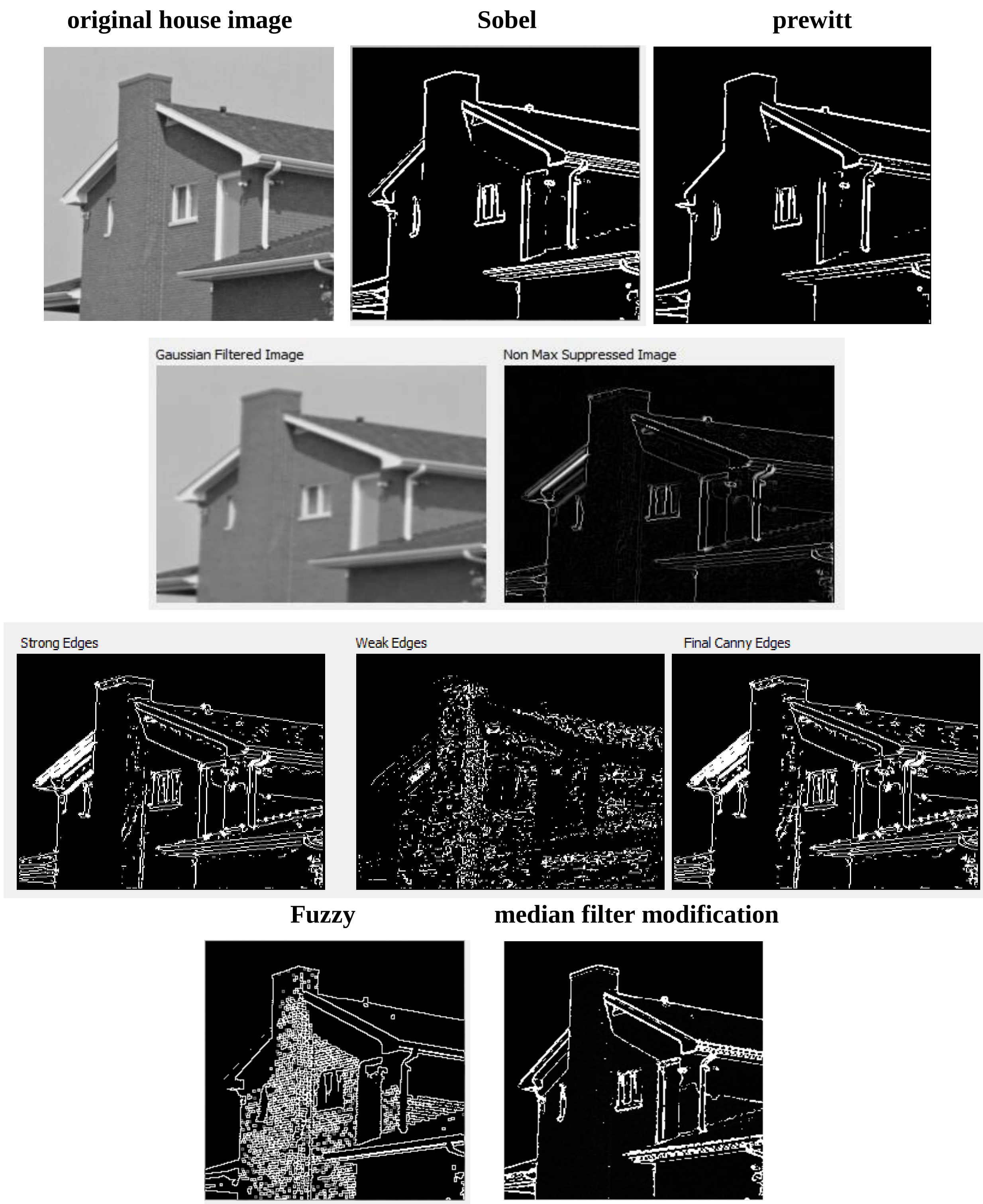

Figure.(8): Original house images and Various types of edges.

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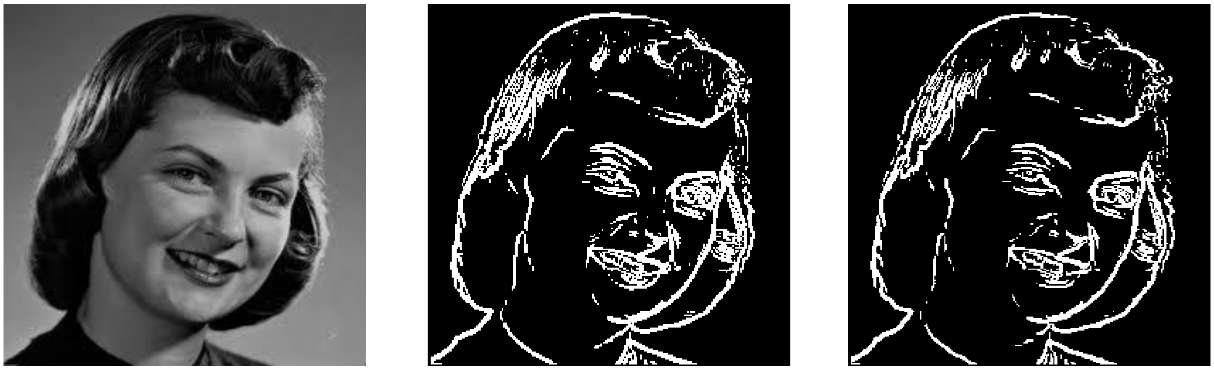
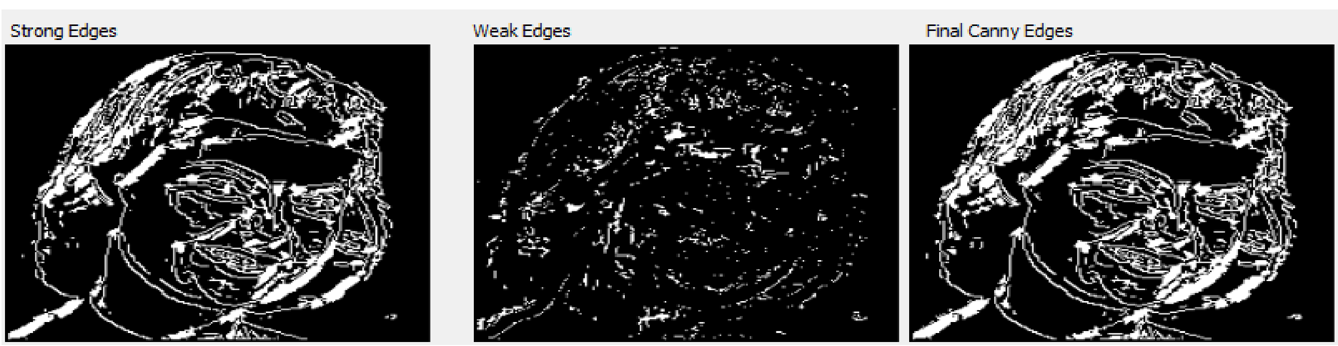
original woman image **Sobel** **prewitt**





Fuzzy **median filter modification**

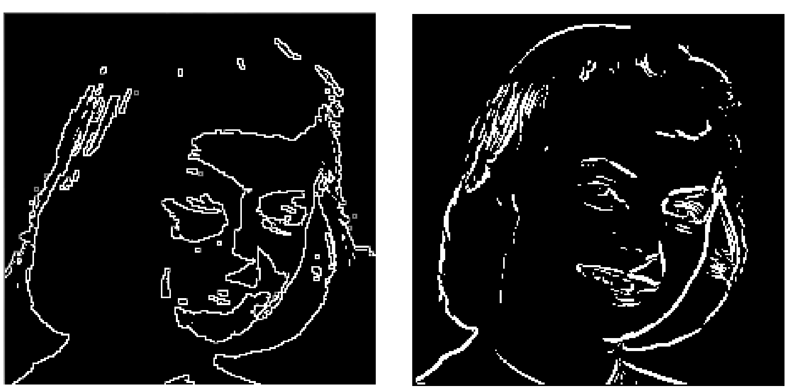


Figure.(9): Original woman image and Various types of edges.

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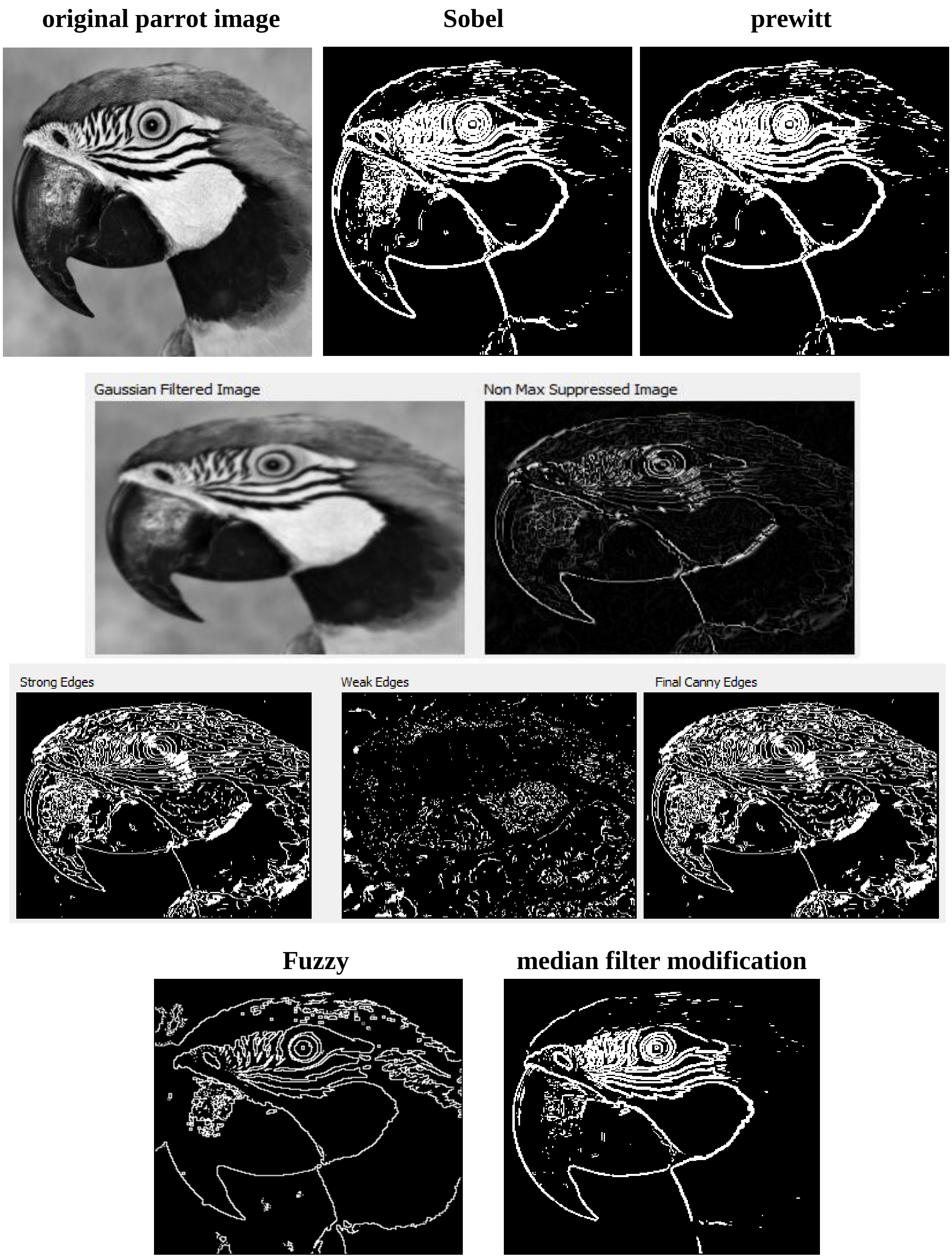

Figure.(10): Original parrot image and Various types of edges.

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Gradient-based algorithms such as the Prewitt filter have a major drawback of being very sensitive to noise. The size of the kernel filter and coefficients are fixed and cannot be adapted to a given image. An adaptive edge-detection algorithm is necessary to provide a robust solution that is adaptable to the varying noise levels to help distinguish valid image contents from visual artifacts introduced by noise as in Figures.(8,9,10) .

The performance of the Canny algorithm depends heavily on the adjustable parameters, σ, which is the standard deviation for the Gaussian filter, and the threshold values, 'T1' and 'T2'. σ also controls the size of the Gaussian filter. The bigger the value for σ, the larger the size of the Gaussian filter becomes. This implies more blurring, necessary for noisy images, as well as detecting larger edges. As expected, however, the larger the scale of the Gaussian, the less accurate is the localization of the edge. Smaller values of σ imply a smaller Gaussian filter which limits the amount of blurring, maintaining finer edges in the image. The user can tailor the algorithm by adjusting these parameters to adapt to different environments.

Canny's edge detection algorithm is computationally more expensive compared to Sobel, Prewitt and Robert's operator. However, the Canny's edge detection algorithm performs better than all these operators under almost all scenarios as in Figures.(8,9,10) .

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4.CONCLUSION

Fuzzy image processing is a powerful tool form formulation of expert knowledge edge and the combination of imprecise information from different sources. The designed fuzzy rules are an attractive solution to improve the quality of edges as much as possible. One past drawback of this type of algorithm was that they required extensive computation. These results allow us to conclude that The implemented FIS system presents greater robustness to contrast and lighting variations, besides avoiding obtaining double edges. It is gave a permanent effect in the lines smoothness and straightness for the curved lines it gave good roundness. In the same time the corners get sharper and can be defined easily.

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