An Entropy Based Thresholding Approach for Image Edge Detection

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***Abstract*— Edge detection is considered as an important research area in the field of image processing and computer vision. Different edge detection methods or operators such as Sobel, Prewitt, Roberts, Laplacian of Gaussian (LoG), Canny, etc. are used for detecting the edges of an image. However, no such edge detection method works well under all the conditions. Edges which are missed by an edge detection method may be detected by another method. This paper proposes an entropy based thresholding mechanism that uses Shannon entropy and Tsallis entropy to detect the edges. This method also use Canny edge detector for gaining the missing edges. The results of proposed method are compared with the existing edge detection methods such as Sobel, Prewitt, Roberts, LoG, Canny and Sayed. Experimental results show that the proposed method provides better results as compared to other methods.**

***Keywords*— Edge Detection, Entropy Based Thresholding, Shannon Entropy, Tsallis Entropy, Canny Edge Detector**

I. INTRODUCTION

A very important area of research in image processing is detecting the edges of an image ([6], [8], [9], [10], [13], [16]). An edge is considered as a set of pixels (connected) which lie on the boundary portion among two regions which varies in their intensity value, and edges arise at different positions of image due to variation of intensity values, discontinuity in depth or surface orientation, changes in material properties. Edge detection of image is nothing but representing sharp discontinuities in the image. Different edge detection techniques are applied in several applications like object identification, image segmentation, and extraction of feature. However, no method works well under all conditions. Edges miss by one method may be detected by other methods.

Many edge detectors like Sobel, Prewitt, Roberts, LoG, Canny are used for edge detection of image ([2], [17], [19], [21]). First derivative (gradient) or second derivative (Laplacian) can be used for such purpose ([7], [12]). The gradient method identifies edges by considering for minimum or maximum in the first derivation process of the image. But the Laplacian based process identifies edges by focusing for the zero crossings in the second derivation process of image. Prewitt, Sobel and Roberts have used two 2-dimensional linear filters for the processing of vertical as well as horizontal edges in separate manner and these operators are gradient based methods. The operators like LoG and Canny focuses on the derivation process of pixels of several images for the purpose of edge detection and these operators are Laplacian based methods. The second derivative is more sensitive to noise.

Image thresholding ([4], [5], [18], [20], [22], [23]) mechanism helps in partitioning an image into two segments: foreground and background, and it is the one of the method used for image segmentation. Generally, entropy describes the degree of randomness, uncertainty or disorder in an image and entropy based image thresholding helps in finding the suitable threshold value which is very much essential in edge detection process ([1], [3], [11]).

Different entropy such as Shannon and Tsallis can be used for such purpose. Shannon entropy measures how much information is needed in order to identify the random samples from a specified probability distribution (PD). Tsallis entropy is a generalized form of Boltzmann-Gibbs (BG) entropy [15].
The main contributions in this paper are presented as follows:

1. An entropy based thresholding edge detection scheme is proposed in order to detect the edges of color and gray scale digital images using Shannon entropy, Tsallis entropy, and Canny edge detector.

2. A global threshold th_1 is calculated using Shannon entropy to find the foreground (object) image and background image. th_1 is applied on the background image to find the image I_1. Then thresholds th_2 and th_3 are calculated by applying Tsallis entropy. th_2 is used on the object image to find image I_2 and th_3 is applied on the background image to find image I_3. Then the three images (I_1, I_2, and I_3) are merged to get the edges in image w of the original image I.
3. Then the result of Canny edge detector (which is applied on original digital image) is merged into the missing values (edges) of w.

4. The results of the proposed edge detection method are produced using MATLAB R2015b. Results show that the proposed method performs better than the other edge detection methods in detecting the edges properly.

This paper is arranged in the following manner: related works are described in Section II, Section III describes the overviews of image thresholding and edge detection mechanisms, Section IV presents proposed methodology, Section V deals with the results and discussion, and conclusion is mentioned in Section VI.

II. RELATED WORKS

Several edge detection operators ([2], [14], [17], [19], [21], [24]) such as Sobel edge detector, Prewitt edge detector, Roberts edge detector, Canny edge detector, LoG edge detector, etc. are used for edge detection of image. However, these operators fail to detect edges perfectly under all conditions. Sayed [3] method is based on entropy-based thresholding mechanism for detecting the edges of images. Shannon entropy and Tsallis entropy are used for the thresholding mechanism. This method has the advantage of robustness and flexibility. This method can be easily implemented and deals with lower computation time. This method works well for gray scale images (digital). However, this method provides thicker edges and also suffers from missing edge problem. It contains some noise values, and it is also not tested for the color images. Katiyar et al. [25] proposed a comparative analysis of common edge detection techniques. The edge detection method such as Sobel, Prewitt, Canny and Laplacian are compared. This paper presents that the performance of Canny edge detection may be better as compared to other method and it may detect lesser number of false edges. However, these techniques may not suppress the broken and false edges.

Wang et al. [17] proposed an improved Canny edge detection algorithm for dealing with existing problems in traditional algorithms. At first, the anisotropic filter is used to de-noise original gray scale images. This method suppresses the noise and preserves the edge feature effectively. Secondly, the high and low thresholds used in Canny operator is optimized using genetic algorithm (GA) on the basis of Otsu evaluation function for avoiding human factors. The presented algorithm may reduce the false negative and may improve the accuracy of detection than traditional operators. The experiment shows that this algorithm may be robust in pedestrian detection. This work enhances the edge detection performance greatly, however there are some places which need further improvement and more suitable parameters of GA can be determined in edge detection process through experiments.

III. THRESHOLDING AND EDGE DETECTION MECHANISM

This section focuses on image thresholding mechanism as well as several edge detection operators.

A. Image Thresholding

In this section, the calculation of threshold values using Shannon entropy and Tsallis entropy [3] is described. The probability of set of source symbols is represented by S, S={s_1,s_2,…s_k} and it must satisfy the condition $\sum_{j=1}^{k} s_j=1$, $0<=s_j<=1$. The Shannon entropy can be calculated as :

$$T(Z)= -\sum_{j-1}^{k} s_j \ln(s_j) \quad (1)$$

where, T(Z) represents the information (average)/output of source and k represents the number of states. If a system is divided into two subsystems (statically independent) X and Y, then the Shannon entropy possess the extensive property (additive property) T(X+Y) = T(X)+T(Y) and it is restricted to BG-Shannon (BGS) statistics. In order to describe the thermo-statistical principle of systems with non extensive property, Tsallis has given a generalized entropic form as follows:

$$T_t=1/(t-1)(1-\sum_{j=1}^{k} S)_j^t \quad (2)$$

where t is the entropic index which is used for characterization of degree of non-extensitivity. By considering the limit t->1, the above formula recovers to BGS entropy. Tsallis entropy has one principle (non-extensitivity) for system (statistically not dependent) which can be represented as follows:

$$T_t(x+y)=T_t(x)+T_t(y)+(1-t).T_t(x).T_t(y) \quad (3)$$

At point (m,n), assume that g(m,n) be the pixel value (gray value) of the pixel. In image (digital) {G(m,n)|mϵ{1,2,…..,U}, nϵ{1,2,…..,V} of size U×V. Let us consider the histogram which can be taken as $h_m(q)$ for qϵ{0,1,2,…..,255} with g as the amplitude at position (m,n). The set of gray levels or pixel levels i.e. {0,1,2,….,255} is represented as F. The optimal threshold is represented as th^*. Let us consider th be the threshold value and Bn={bn_0,bn_1} be a binary gray level pair with {bn_0,bn_1}ϵ F. Normally the value of bn_0 and bn_1 can be taken as 0 and 1 respectively. At gray level th, the output of image thresholding function g(m,n) is a binary function $g_{th}(m,n)$ in such a manner that $g_{th}(m,n)=bn_0$ if $g_{th}(m,n)<=th$, otherwise $g_{th}(m,n)=bn_1$. Assume that $s_i=s_1,s_2,….,s_k$ be the PD for a digital image having k number of gray levels (pixel levels). Two PDs can be derived for foreground or object (class X) and background (class Y) which is mentioned as follows:

$$s_x=s_1/S_X,s_2/ S_X,…..,s_{th}/ S_X \text{ and } s_y=s_{th+1}/S_Y,s_{th+2}/ S_Y,…,s_k/ S_Y \quad (4)$$

$$\text{where } S_X= \sum_{j=1}^{th} s_i \text{ and } S_Y=\sum_{j=th+1}^{k} s_i \quad (5)$$

The Tsallis entropy having order t for each PD is given as:

$$T_t^X(th)=(1/t-1)(1-\sum_{j=1}^{th} s^t{}_X \quad \text{and} \quad T_t^Y(th)=(1/t-1)(1-\sum_{j=th+1}^{k} s^t{}_Y \quad (6)$$

The Tsallis entropy $T_t(th)$ depends on the threshold value th parametrically for object image, background image and it is calculated as the addition of each and every entropy. When $T_t(th)$ is maximized, then the optimal threshold value can be calculated as follows:

$$th^*(t)=\text{Avg max}_{th\epsilon F} [T_t^X(th)+ T_t^Y(th)+(1-t). T_t^X(th).T_t^Y(th)] \quad (7)$$

In the proposed process, a binary image is created by selecting appropriate threshold value by the help of Tsallis entropy. The process consists of considering each and every pixel of original digital image and producing an image (new), such that $g_{th}(m,n)=0$ if $g_{th}(m,n)<=th^*(t)$,otherwise gth(m,n)=1 for every mϵ{1,2,…,U}, nϵ{1,2,….,V}. When t->1,then the threshold value mentioned in equation 2, is same as the value calculated by Shannon's process. So our method includes Shannon's method and in order to get optimal threshold at t->1, the following formula is used.

$$th^*(1)=\text{Avg max}_{th\epsilon F}[T^X(th)+T^Y(th)] \quad (8)$$

B. Edge Detection Mechanism

Several edge detection operators are used for edge detection of color and gray scale images. Some of the operators are described as follows:

1) Sobel Edge Detection Operator:

Sobel edge detection operator is considered as a gradient-based method. It applies a two dimensional spatial gradient measure on image and focuses on high spatial frequency that leads to edges. It consists of two 3×3 masks named as SM_X and SM_Y as shown in Fig. 1, one for horizontal calculation (SM_X) and other for vertical calculation (SM_Y) for detection of edge of image. Here the gradient magnitude can be calculated as $((SM_X)^2+(SM_Y)^2)^{1/2}$ and the approximate gradient magnitude can be calculated as $|SM_X|+|SM_Y|$.

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

SM_X

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

SM_Y

Fig. 1 Sobel Edge Detection Operator with 3×3 Masks

2) Prewitt Edge Detection Operator:

Prewitt edge detection operator is based on discrete differentiation operation that computes the gradient approximation of image intensity function. The properties of this edge detector are similar with the properties of Sobel edge detector. It also consists of two 3×3 masks named as PM_X and PM_Y as shown in Fig. 2, one for horizontal calculation (PM_X) and other for vertical calculation (PM_Y) for detection of edge of image. Here, the gradient magnitude and approximate gradient magnitude can be calculated in the similar manner as in Sobel edge detector.

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

PM_X

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

PM_Y

Fig. 2 Prewitt Edge Detection Operator with 3×3 Masks

3) Roberts Edge Detection Operator:

The Roberts edge detector has a simple structure. It is also a gradient based method. It consists of two 2×2 masks named as RM_X and RM_Y as shown in Fig. 3, one for horizontal calculation (RM_X) and other for vertical calculation (RM_Y) for detection of edge of image. Here, the gradient magnitude and the approximate gradient magnitude can also be calculated in the similar manner as in Sobel and Prewitt edge detectors.

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

RM_X RM_Y

Fig. 3 Roberts Edge Detection Operator with 2×2 Masks

4) LoG Edge Detection Operator:

LoG is a second order derivative operator and it focuses on zero crossings points in the image. It detects thin and sharp edges. This edge detector is very sensitive to noise. It can use a single mask M_{XY} of size 5×5 as mentioned in Fig. 4 for edge detection of image instead of using two different masks for horizontal and vertical calculations involved in Sobel, Prewitt and Roberts edge detection process. It uses Gaussian smooth filter to reduce the noise from image.

0	0	1	0	0
0	1	2	1	0
1	2	-16	2	1
0	1	2	1	0
0	0	1	0	0

M_{XY}

Fig. 4: LoG Operator with 5×5 Mask

5) Canny Edge Detection Operator:

Canny edge detection operator is known as one of the optimal edge detectors and it is most commonly used in practice. It detects edges based on specific criteria (parameters dependent) and it deals with multiple stage process. Here Gaussian filter is used for smoothening the image. A two dimensional first derivative operator is used on the smoothened image in order to focus the portion with high first spatial derivatives. In gradient magnitude image, edges rise with ridges. The algorithm for Canny edge detection process has the following steps shown below:

Step 1: Gaussian filter is applied for reducing the noise from image.

Step 2: Edges of the image are found out using appropriate edge detector. Sobel edge detector can be used for such purpose.

Step 3: Edge direction is found out using the formula $\theta=\tan^{-1}(SM_Y/SM_X)$ (SM_Y and SM_X are specified in Fig. 1)

Step 4: Non-maxima suppression process is applied in order to suppress the pixel value which is not recognized to be an edge and it provides thin lines of edge.

Step 5: In order to remove streaking, hysteresis thresholding is used.

IV. PROPOSED METHODOLOGY

The methodology describes about the optimal threshold calculation and proposed edge detection mechanism.

A. Steps for Calculation of Optimal Threshold Value (th)*

Input: A digital image I of size U×V

Output: th^* of I, for t>=0

Step 1: Assume that g(m,n) be the gray value (pixel value) of the pixel at (m,n) position, m=1,2,….,U and n=1,2,…,V
Step 2: Calculation of PD $0<=s_i<=255$
Step 3: For all th ϵ{0,1,2,…,255}

- calculate S_X ,S_Y , s_X , s_Y using equations 4 and 5
- calculate optimal threshold value th^* using equation 7

B. Proposed Edge Detection Mechanism

For edge detection of the image, different masks are used. A spatial filter edge detector can be provided as a mask ms of size i × j. It is assumed that $i=2*d_1+1$ and $j=2*d_2+1$ where d_1, d_2>=0. For the convenience, the mask of size 3×3 is used and the mask coefficients are mentioned in the Table I.

TABLE I: Required mask with size 3×3

ms(-1,-1)	ms(-1,0)	ms(-1,1)
ms(0,-1)	ms(0,0)	ms(0,1)
ms(1,-1)	ms(1,0)	ms(1,1)

TABLE II: Image region below the mask (in Table 5)

B(m-1,n-1)	B(m-1,n)	B(m-1,n+1)
B(m,n-1)	B(m,n)	B(m,n+1)
B(m+1,n-1)	B(m+1,n)	B(m+1,n+1)

TABLE III: Mask coefficients

1	1	1
1	*	1
1	1	1

The image region below the mask (Table I) is represented in Table II. In our method, a binary image is created by selecting a threshold value with the help of Shannon and Tsallis entropy. The mask is used on the created binary image and all the mask coefficients are set to 1 except the center and the center is represented as * as mentioned in Table III. The probability of each and every pixel (central) of image is calculated after moving the mask upon the binary image and then the entropy of each central pixel of the image below the mask is defined as $E(Cp) = -T_{cp} \ln(T_{cp})$, where T_{cp} is the central pixel (C_p) probability of the binary image. When $T_{cp}=1$ then entry is zero. So, if the gray level (pixel level) of all pixels is homogeneous then $T_{cp}=1$ and E=0 and here the central pixel is not the edge pixel. Secondly, Canny edge detector is used in this method in order to get better results by adding the missing edges.

C. Steps for Edge Detection

Step 1: The global threshold value th_1 is calculated using Shannon entropy mentioned in equation 8. Here the digital image is portioned into two segments foreground (object) and background by using th_1.

Step 2: Tsallis entropy mentioned in equation 7 is used with t=1/2 in order to write the equation 6 as follows:

$$T_{½}^{X}(th)=2 \sum_{j=1}^{th} |(s_X)^{1/2}|-2 \quad \text{and} \quad T_{½}^{Y}(th)=2 \sum_{j=th+1}^{k} |(s_Y)^{1/2}|-2 \tag{9}$$

So, the equation is represented as follows:

$$th^{*}(1/2)=\text{Avg}\max_{th\epsilon F}[(\sum_{j=1}^{th} |(s_X{}^{1/2})|)(\sum_{j=th+1}^{k} |(s_Y{}^{1/2})|)-1] \tag{10}$$

Local threshold values th_2 and th_3 of the object image and background image are calculated by using equation 10.

Step 3: Proposed edge detection algorithm is applied with threshold values th_1, th_2, th_3 and their results are merged to get the output image w.

Step 4: Canny edge detection operator is applied on the original digital image to generate the result (edges) and this result is merged into the missing values (edges) of w to generate the final resultant image (Z) using Steps 5-8.

Algorithm 1: Pseudo Code for edge detection

Input: Image I with size U×V and th^*

Output: Output image Z of I.

```
Step 1: Binary image creation for all m,n if B(m,n)<=th* then B(m,n)=0 else g(m,n)=1
Step 2: Creating a mask ms (3X3) where a=(i-1)/2 and b=(j-1)/2
Step 3: Produce a U×V output image, w: for all m and n, set w(m,n)=B(m,n)
Step 4: Edge pixel checking : for all n ϵ{b+1,….V-b}, mϵ{a+1,….U-a}, s=0;
        for all c ϵ {-b,….b} and dϵ{-a,….a}
                if (B(m,n)=B(m+d,n+c)) then     s=s+1
        if (s>6) then w(m,n)=0 else w(m,n)=1

Step 5: bw1 = edge(I,'Canny');
Step 6: for p=1 to U
                for q=1 to V
                    if(w(p,q) = = 0)
                        fd(p,q)=ceil(bw1(p,q));
                   else
                        fd(p,q)=w(p,q);
                  end
                end
            end
Step 7: K = wiener2(fd,[5 5]);
Step 8: Z = imsharpen(K); // Edge Detection
```

The performance of the proposed edge detection method is analyzed using MATLAB R2015b. MATLAB (Matrix Laboratory) ([26], [27]) is developed by MathWorks which provides a numerical computing environment for implementing algorithms, plotting graphs, data analysis, designing user interfaces, interfacing with other programming languages, etc. It is used for image and video processing using matrix manipulations. Therefore, in this work this tool is used for performance evaluation. Here, MATLAB toolbox images such as spine, trees, mandi, office_6 and one normal image such as tumor_mri with different sizes and resolutions are taken to test the proposed method and compare its result with Sobel, Prewitt, Roberts, LoG, Canny, and Sayed [3] schemes. The experimental results are mentioned in Fig. 5 to Fig. 9.

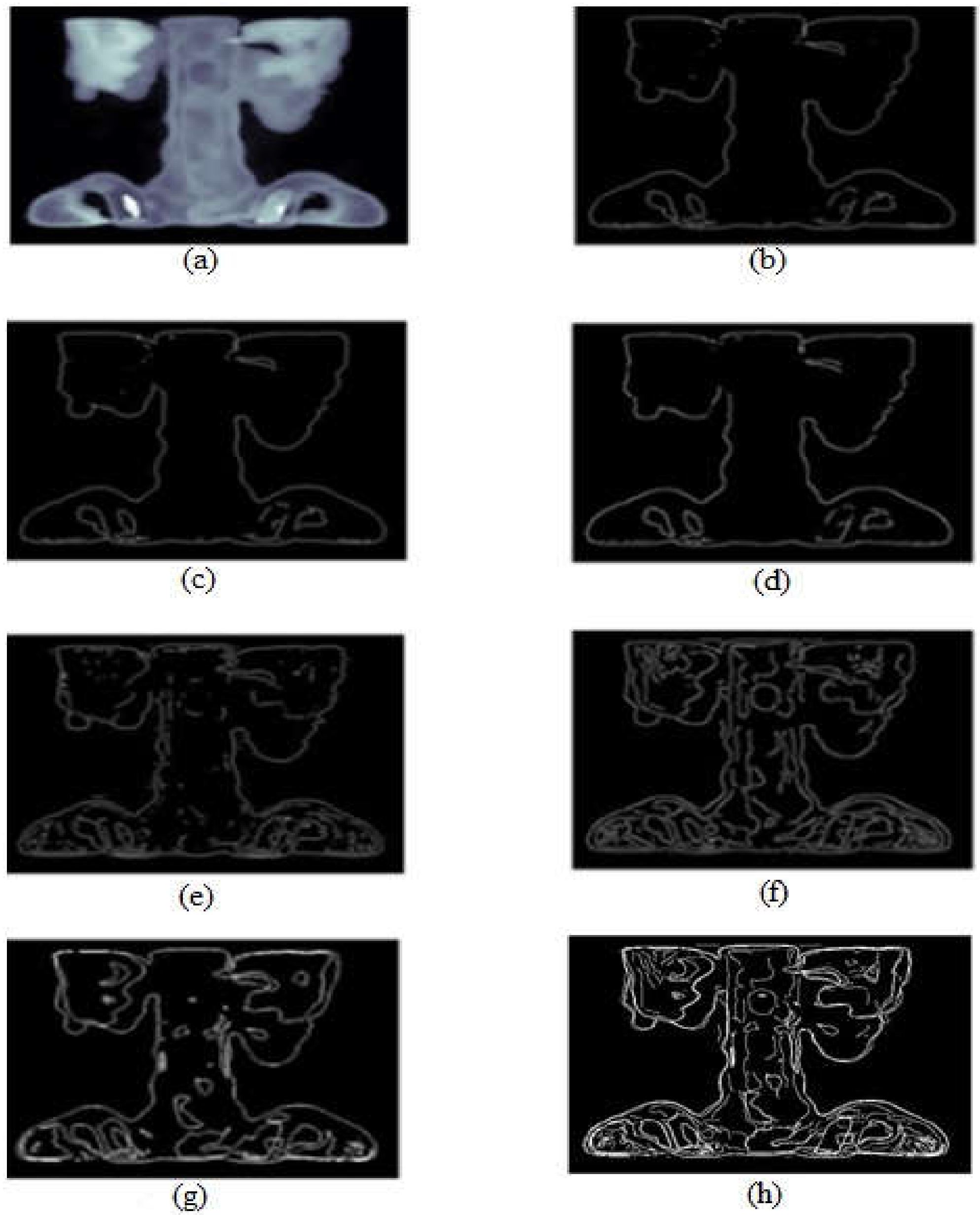

Fig. 5 (a) Original spine image with 490×367 pixels. (b) Result by applying Sobel edge detection operator. (c) Result by applying Prewitt edge detection operator. (d) Result by applying Roberts edge detection operator. (e) Result by applying LoG edge detection operator. (f) Result by applying Canny edge detection operator. (g) Result by applying Sayed [3] method. (h) Result by applying Proposed method.

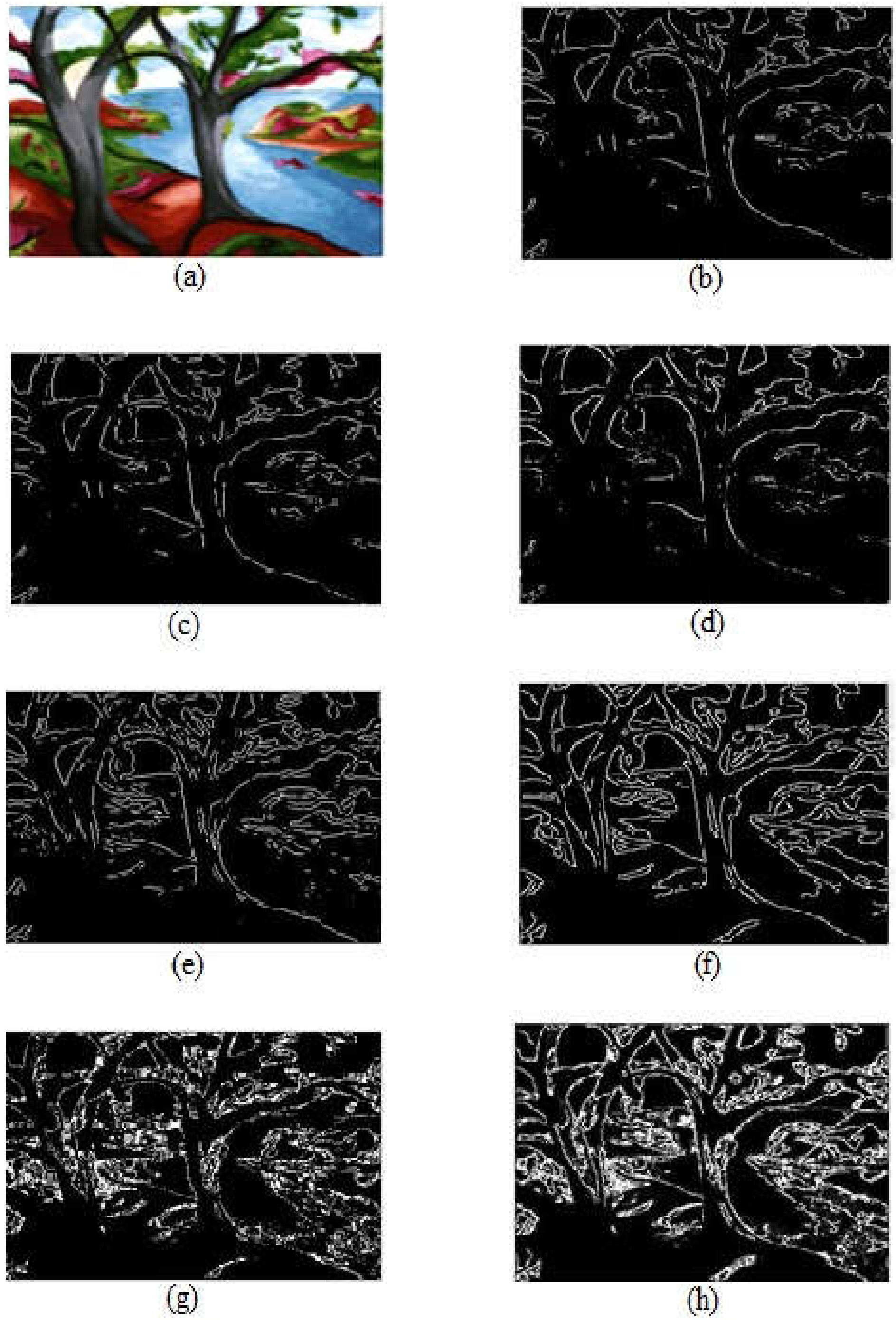

Fig. 6 (a) Original trees image with 350×258 pixels. (b) Result by applying Sobel edge detection operator. (c) Result by applying Prewitt edge detection operator. (d) Result by applying Roberts edge detection operator. (e) Result by applying LoG edge detection operator. (f) Result by applying Canny edge detection operator. (g) Result by applying Sayed [3] method. (h) Result by applying Proposed method.

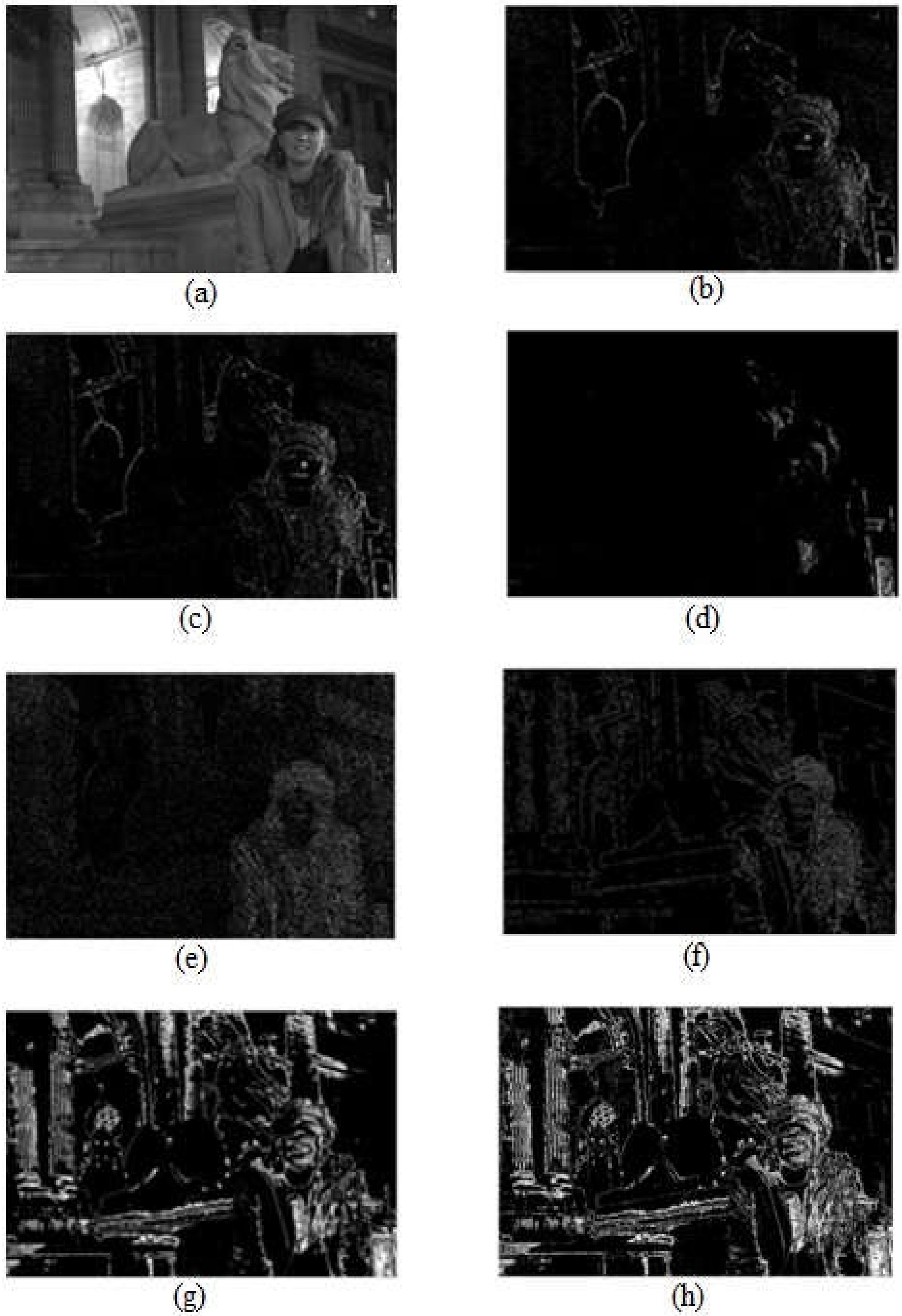

Fig. 7 (a) Original mandi image with 3039×2014 pixels. (b) Result by applying Sobel edge detection operator. (c) Result by applying Prewitt edge detection operator. (d) Result by applying Roberts edge detection operator. (e) Result by applying LoG edge detection operator. (f) Result by applying Canny edge detection operator. (g) Result by applying Sayed [3] method. (h) Result by applying Proposed method.

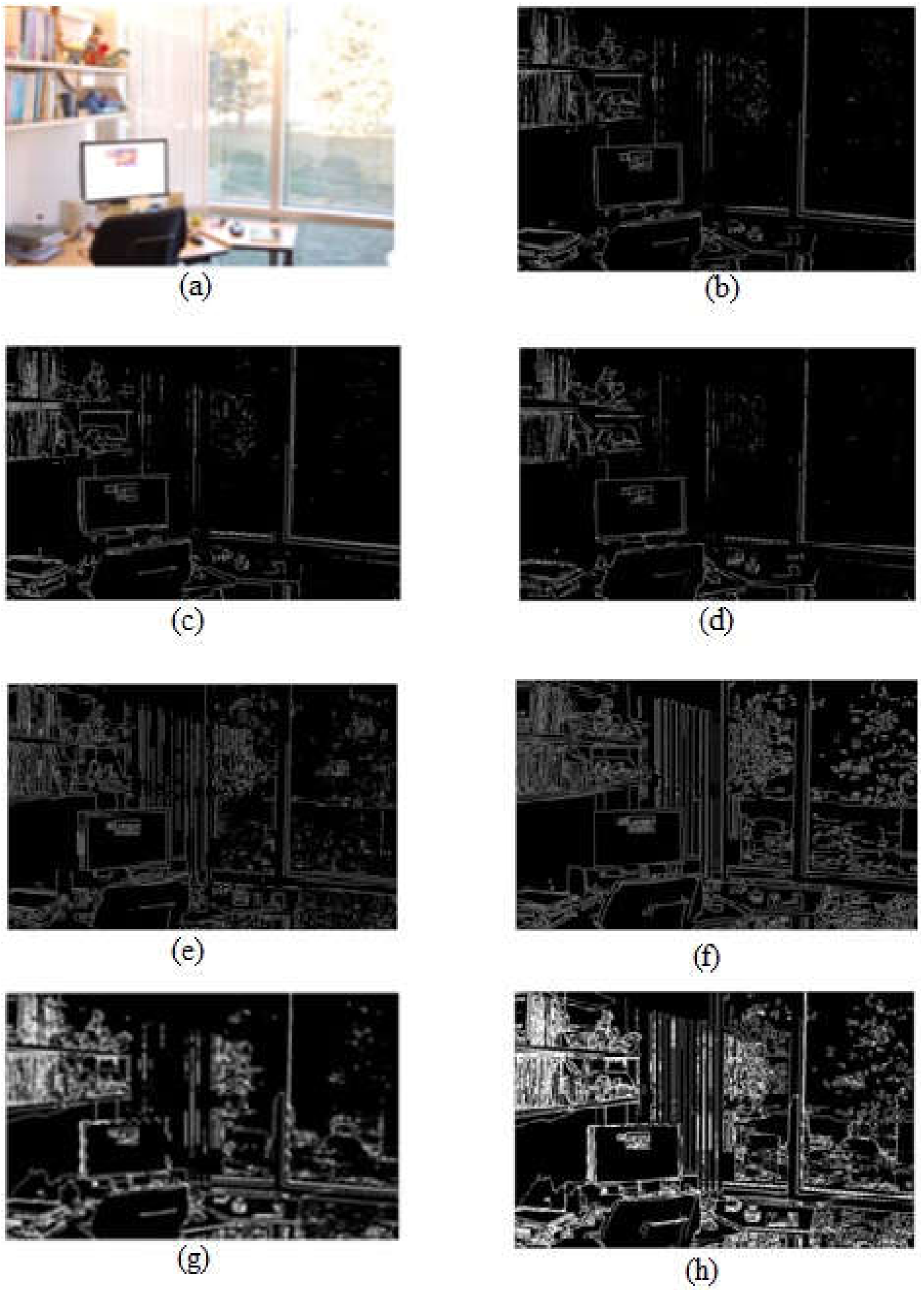

Fig. 8 (a) Original office_6 image with 903×600 pixels. (b) Result by applying Sobel edge detection operator. (c) Result by applying Prewitt edge detection operator. (d) Result by applying Roberts edge detection operator. (e) Result by applying LoG edge detection operator. (f) Result by applying Canny edge detection operator. (g) Result by applying Sayed [3] method. (h) Result by applying Proposed method.

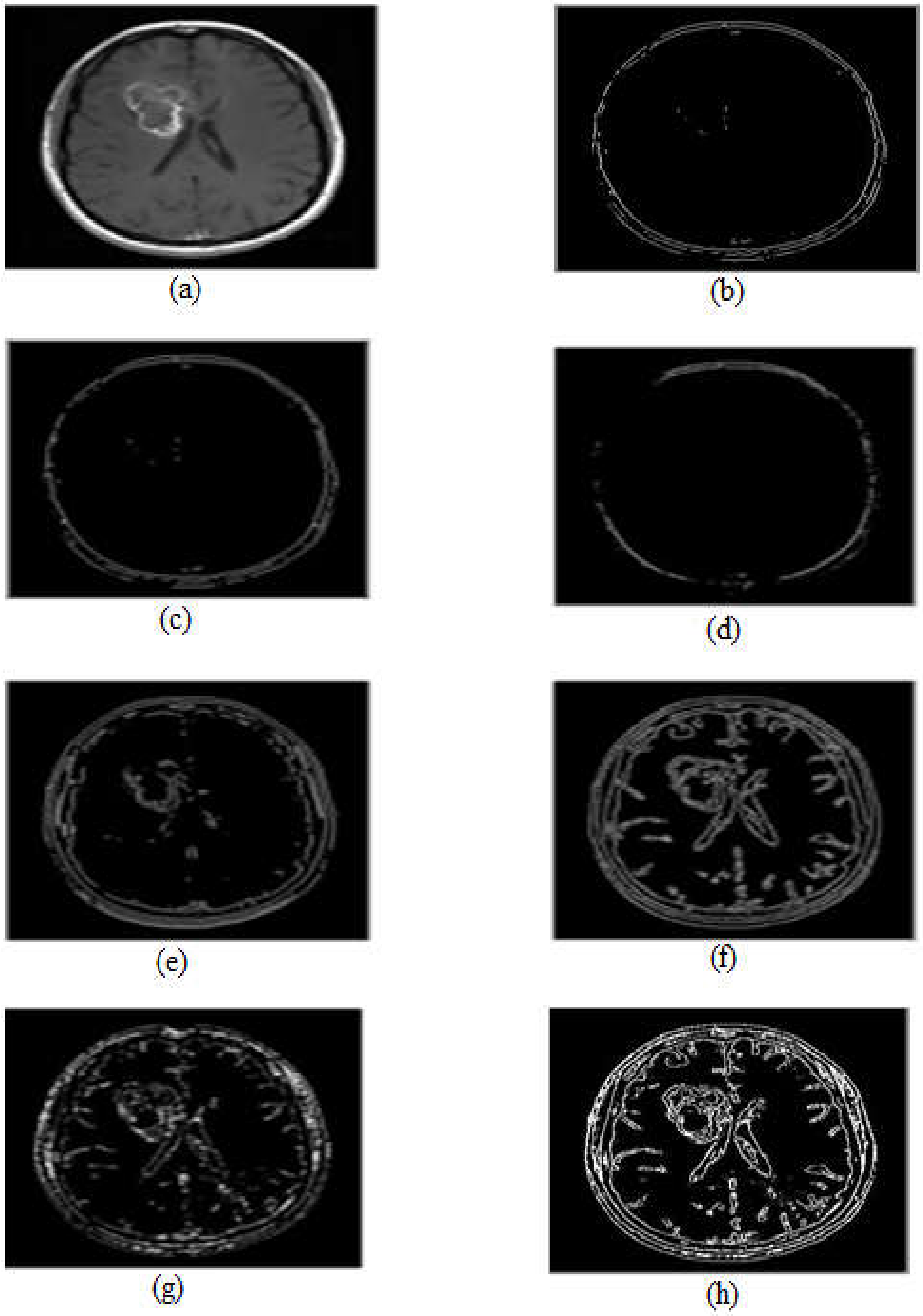

Fig. 9 (a) Original tumor_mri image with 300×336 pixels. (b) Result by applying Sobel edge detection operator. (c) Result by applying Prewitt edge detection operator. (d) Result by applying Roberts edge detection operator. (e) Result by applying LoG edge detection operator. (f) Result by applying Canny edge detection operator. (g) Result by applying Sayed [3] method. (h) Result by applying Proposed method.

Fig. 5 to Fig. 9 shows the results of Sobel, Prewitt, Roberts, LoG, Canny, Sayed [3] and the proposed method in (b), (c), (d), (e), (f), (g), and (h) respectively. From the observation (subjective method of analysis), the proposed method shows better edges in terms of clarity and displays accurate edges as compared to other methods. However, the edges are thick in some locations. Whereas, the result of Sayed [3] method displayed in (g) detect the edges in a better way as compared to results of other methods (b, c, d, e, and f), however it shows thick and missing edges, and it also consists of noisy values. The proposed method shows the edges prominently (that means, more accurate edges and has low noise values).

VI. CONCLUSION

The proposed method presented in this paper uses entropy based thresholding mechanism for detecting the edges of an image. For detecting the edges Shannon entropy, Tsallis entropy, and Canny edge detector are used. The main benefit of this method is its easy implementation for both color and gray scale images. From the analysis of the experimental results mentioned in Fig. 5 to Fig. 9, it is concluded that the proposed method provides better results (edges) in terms of clarity and more accurate edges for both gray scale and color images as compared Sobel, Prewitt, Roberts, LoG, Canny and Sayed [3] methods. The future work will focus in reducing the thickness of the edges.

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