Volume 3, Issue 12, December 2013 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Novel Approach for Discovery of Edges in Medical Images

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Image Segmentation is one of the core areas of digital image processing and one of the most important applications of image segmentation is edge detection. Edge detection is the process of detecting of abrupt discontinuities in an image. Boundaries are characterized by edges and edge detection is one of the most difficult tasks in image processing which has its own applications in medical image analysis and other domains. The problem of edge detection although it is fundamental and is existing since years but it is still an area where there is still scope of research. It is found that previous algorithms or methods were not able to produce ideal or optimized results. This paper presents a novel approach for the extraction of edge pixels from images with help of a new mathematical function which is used to find their directions also. A suitable thresholding approach has been used to suppress non edge points. The results are quite promising and justify the work carried out.

Keywords**—** Edge Detection, Threshold, Canny, Sobel, Edge map

I. Introduction

Edge may be characterized as boundary between an object and background. Edge detection is a classical problem in the field of computer vision and image processing. It is crucial to understand the mechanism of Edge Detection as this is the forefront for the development of applications in domains like tumor detection, object detection and other medical imaging applications.. Edge detection is one of the starting steps for number of operations in medical image analysis where it can be utilized to detect irregularities like tumors, disjoints etc. The goal of the edge detection process in a digital image is to determine the frontiers of all represented objects by automatically processing color or gray level information in each pixel. The image intensity shows sudden changes at edges. Edge detection usually involves the calculation of derivative of the image intensity so that relative change can be measured and if magnitude of this change is high pixel is considered as edge pixel. Purpose of all edge detection algorithms is to detect and highlight these discontinuities. This paper presents a novel approach for the detection of these discontinuities in medical images. This paper is organized as follows: after this introductory part, section II focuses on some of the work already carried out in field of edge detection, section III introduces the proposed method, results are included in next section followed by conclusion and future directions.

II. LITERATURE SURVEY

The most commonly used methods used for edge detection include some of the very common and traditional techniques like Sobel, Prewitt, Kirsch and canny operators [1, 2, 3, 4]. Sobel operator utilizes two masks S_x and S_y, and perform convolution on the gray image to obtain edge intensities E_x and E_y in the horizontal and vertical directions. Sobel method has disadvantage that edges detected by it are usually thicker which can be improved by Canny method. Canny can utilize edge intensities found by Sobel to calculate edge angle as $\tan^{-1}E_y/E_x$. However both Canny and Sobel will obtain zero intensity if a line of one-pixel-width passes through the mask and then the incorrect edge called “double edges” on the both sides of this line will be generated. Edge intensity values obtained by the Sobel method and Canny method are very large therefore they need a mechanism to set the threshold based on many heuristic attempts in an unknown range. The recent focus on edge detection has been the application of principles of soft computing like Neural Networks, Fuzzy Logic and Genetic Algorithms at [5]-[13]. Soft computing is different from conventional (hard) computing techniques which are based on the concept of precise modeling and analyzing to yield accurate results where as human mind is the role model of soft computing [14]. Soft computing approaches tend to solve the problem of edge detection as an optimization of certain functions or features subject to certain constraints. Studies pertaining to neural networks can be found at [5]-[6] and those referring to fuzzy logic and genetic algorithms are available at [7]-[9]and [10]-13] respectively. There has been fusion of traditional studies and soft computing techniques available at [10] in which performance of sobel operator has been improved by Genetic Algorithms. Soft computing approaches have advantages as these can accommodate principles of uncertainity but suffers from execution time constraints. The concept of inter-set and intra-set differences to determine accurate edge pixel intensity and edge direction has been provided by[15] but this technique may at times suffer computational delays as there is no mechanism to limit the number of segments in an image which can be serious problem for medical images where intensity variations are very small.

There has been numerous work in field of edge detection but this is one such area where improvements can still be made. The application of edge detection to medical images is still an area which is left untouched. This study is an extension of the work [15] in which authors had used some mathematical functions to calculate intensity of pixels and thereafter performing thresholding with respect to different segments of the image. The improvement to [15] is sought by limiting number of segments to a desired value which will be calculated by k-mean algorithm and results are taken on medical images specifically PET scan images of Liver instead of standard test images.

III. Proposed Method

The proposed algorithm is based on finding edge pixels using suitable objective function and performing thresholding. Thresholding approach used is very novel as rather than fixing threshold value to a controlled number, algorithm calculates different threshold value for different segments. A mask in the image is considered and two different sets generated from this mask are used to define a function. The values of this function will determine the edge intensity and edge direction for each pixel in the mask. After all the edge points have been processed thresholding is applied to suppress non-edge pixels. Consider 3×3 mask as defined in Fig. 1. We will consider four possible directions to which an edge pixel can belong (Fig. 2). Two set S0 and S1 can be calculated for each direction.

Direction 1:- S0={p1,p2,p4,p5,p7,p8} and S1={p3,p6,p9}.
Direction 2:- S0={p1,p2,p3,p4,p5,p6} and S1={p7,p8,p9}
Direction 3 :- S0={p1,p2,p3,p5,p6,p9} and S1={p4,p7,p8}
Direction 4:- S0={p1,p2,p3,p4,p5,p7} and S1={p6,p8,p9}

We define a function to determine edge intensity corresponding to the edge direction-i where i ranges from 1 to 4. The function is given by (I) and is defined as

(x-1,y+1) p1	(x,y+1) p2	(x+1,y+1) p3
(x-1,y) p4	(x,y) p5	(x+1,y) p6
(x-1,y-1) p7	(x, y-1) p8	(x+1,y-1) p9

Fig: 1: 3X3 mask

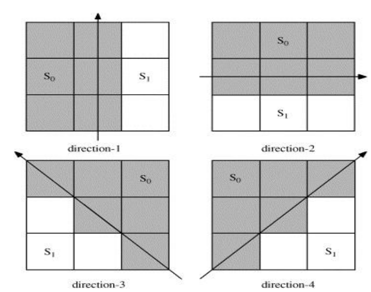

Fig 2: Four possible directions of edges

$$f_i = (L-1)\frac{N_f}{D_f} \quad \text{I}$$

numerator and denominator for the function may be defined by (II) and III respectively

$$N_f = \min\left(1, \frac{|m_0 - m_1|}{w_1}\right) \quad \text{II}$$

$$D_f = 1 + \frac{1}{15}\sum_{p_m,p_n \in S_{0_{m>n, m\neq n}}} \min\left(1, \frac{|p_m - p_n|}{w_2}\right) + \frac{1}{3}\sum_{p_m,p_n \in S_{1_{m>n, m\neq n}}} \min\left(1, \frac{|p_m - p_n|}{w_2}\right) \quad \text{III}$$

The respective values for m_0 and m_1 are defined as $m_0 = (\frac{1}{6})\sum_{p_i \in S_0} P_i$ and $m_1 = (1/3)\sum_{p_i \in S_i} P_i$.

The values of m_0 and m_1 correspond to the average of intensity values for set S_0 and S_1 and values of numerator and denominator are used to measure inter set and intra-set differences. It is clear that edge intensity will be large and compactness of sets S_0 and S_1 will be high if inter-set distance between S_0 and S_1 in the mask is large and the intra-set distances of S_0 and S_1 is small. Therefore a function is defined that calculates distances described above in order to estimate the edge intensity for different values of S_0 and S_1 for different directions. For an 8-bit gray level image numerator N_f defines the inter-set distance between S_0 and S_1. If the inter-set distance between S_0 and S_1 is greater than the gray level w_1 then the edge intensity is large and a linear function will be used to describe N_f only if the inter-set distance is within the interval [0, w1]. The intra-set distance is taken as sum of two degrees of the distance within S_0 and S_1 as denominator D_f. The edge intensity is small if the the intra-set distance is larger than w_2 gray levels. A linear function is used to represent intra-set distance if and only if the intra-set distance is within the interval $[0,w_2]$. The values of w_1 and w_2 are selected after performing series of experiments and are set to specific values depending upon the image in question.

Four different values corresponding to four different directions are calculated. The edge intensity E(x,y) and the edge direction D(x,y) for the center pixel (x,y) in the mask is defined as

$$E(x,y) = \max(f_1, f_2, f_3, f_4) \quad \text{and} \quad D(x,y) = Arg(\max(f_1, f_2, f_3, f_4)) \quad \text{IV}$$

The edge map and direction map for each pixel (x, y) in the image are generated. Once edge map and direction map for the whole image is obtained image is divided into different segments using k-mean clustering and a threshold value (T) is calculated for each cluster. Number of clusters is inputted by the user. Threshold value for each cluster is calculated by averaging of all intensity value of pixels in that cluster and dividing by number of pixels present. Egde map value and Threshold value will determine whether a pixel will qualify as edge pixel or not and follows below defined criteria.

- If E(x,y)<T, where T is a threshold, pixel is discarded .

-If E(x, y) >= T, means center pixel is an edge point and belongs to any one of the possible directions when any one of the following four cases occurs.

D(x,y) =1 and E(x,y)>E(x-1,y) & E(x,y)>E(x+1,y)

D(x,y)=2 and E(x,y)>E(x,y-1) & E(x,y)>E(x,y+1)

D(x,y)=3and E(x,y)>E(x-1,y-1)&E(x,y)>E(x+1,y+1)

D(x,y)= 4 and E(x,y)>E(x-1,y+1) & E(x,y)>E(x+1,y-1)

IV. Results and Discussions

To justify the usefulness of our method, the proposed method was simulated In MATLAB and Medical scan images of various patient having tumors in Liver were taken from a reputed hospital and experiments were performed on patients selected randomly. The images were first converted to grey scale images and then results were taken. This section presents the outcome of proposed method as applied to 4 different patients. Two of the most well known classical edge detection operators are also applied to same image and results are compared with the proposed method.

Experiment 1: Consider PET scan image of “Liver” for a patient having tumor upper left corner(red). Fig 3 presents the results of our method with w1=95 and w2=40. Output of above figure shows that the proposed method performs far better than canny and sobel. Both canny and sobel detected incomplete or false edges where as proposed method was able to detect edges without false contours and continuity of the edges is uniform.

Fig 3:- Comparison with (a) Original (b)Sobel (c) Canny (d) Proposed method

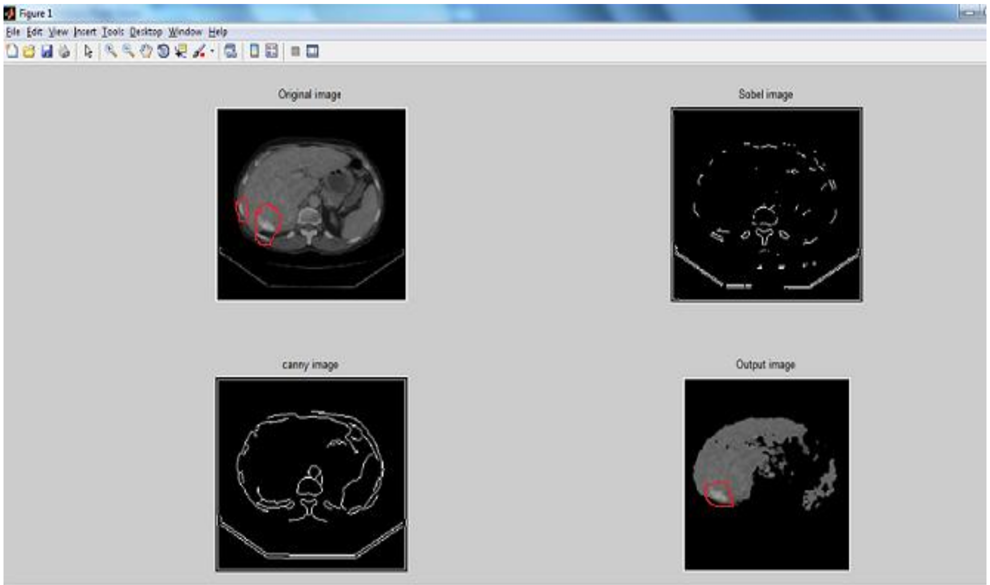

Fig 4:- Comparison with (a) Original (b) Sobel (c)Canny (d) Proposed method

Experiment 2: Consider another PET scan image of Liver for patient having presence of small tumors in lower left portion (red). Fig 4 shows the original image and outputs of three different algorithms with w1=75 and w2=45. The edges detected by proposed method are complete and true. It is observed that Canny at some places detected edges that were not true and missed on a large number of edges and Sobel performed worse as it failed to detect even thicker edges in the background. While all algorithms failed to detect very tiny irregularities the performance of proposed method is far better as compared to canny and sobel.

Conclusion and Future Direction

This study presents an approach for the detection of discontinuities in medical images. The approach is based on defining a mathematical function to find change in intensities for pixels and there after applying varying threshold to different segments to overpower non-edge pixels. Results are taken on PET images of Liver where there is very small difference in the intensity values of the various organs. The proposed method performs far better than traditional operators like canny and sobel and was able to detect very thin and continuous edges. Although proposed provides good results but its ground truth values are still required to be verified by medical practitioners and methods may require improvements when size of discontinuity gets very small. The study is significant as there is dearth of medical practitioners in a developing country like India and can help medical practitioners to focus directly on areas of tumor only. This study can be followed by post processing steps to improve the detected area and can help in building more elegant system which can also determine the nature of tumor to be benign or malignant.

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