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Improved Watershed Algorithm with Marker Controlled Technique for Biomedical MRI Images

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***Abstract*— Image segmentation is the process of highlighting or extracting a small portion/region of the image to get clear and precise information. There are various techniques to carry out segmentation, based on the image characteristic of interest. Watershed method is one such technique to segment an image and is obtained by hybridizing the edge and region based techniques. This method gives more number of regions in an image than its parental techniques. Due to its autonomous nature, many a times the conventional watershed algorithm results in over segmentation. To overcome this problem, marker controlled technique is often used to reduce the over-segmentation. In this paper a new algorithm is proposed to use along with the marker controlled technique to improve the quality of watershed algorithm by reducing the over-segmentation. We compare the proposed algorithm with conventional watershed algorithm to show the superiority of the proposed algorithm.**

***Keywords*— Image segmentation, watershed algorithm, marker controlled technique, unsharping.**

I. INTRODUCTION

Image segmentation is a process of detachment of small region in a whole image to extract more details. Segmenting the image is subjective in nature and varies from user-to-user depending on the nature of image as well as applications. It is also one among the most widely researched areas and is still open to obtain autonomous methods that suits variety of image types.

Image segmentation can be done in three fundamental ways; by setting threshold on the intensity values, by extracting the edge components and by growing the regions using test pixels (Seeds). There are some new methods which are hybrid methods and few others like cluster based methods, graph cut methods and pixon based methods are also used.

Edges are the drastic change in intensities between the neighbouring pixels. The edges in an image correspond to the boundary between two regions or objects in an image. As a result extracting these edges makes it easy to segment regions. There are various operators used to extract edges and are discussed briefly in next section.

Regions in an image are the set of pixels that share similar characteristics. The uniformity between the neighbouring pixels decides the superiority of the segmentation. The region can be either 'grown' or 'split & merged' depending on the nature of the algorithm. These are briefly introduced in sections that follow.

Watershed algorithm is a hybrid of conventional methods used for segmentation. It also uses morphological operations to achieve the purpose. This method constructs a dam when two neighbouring regions are about to merge. Though it gives more segmented regions than region based method, it suffers from major drawback of over-segmentation. In this paper an effort is made to reduce over-segmentation.

The paper is organised as follows: section II describes briefly edge based method of segmentation; section III describes region based method; section IV is on watershed method; section V is methodology followed to arrive at our algorithm; section VI highlights the obtained results and discussions and section VII throws light on future work.

II. EDGES IN AN IMAGE

Edges in an image are the significant abrupt changes, usually local intensity levels, between neighboring pixels in a particular direction. The edges are the effects of boundary established between objects. Edge based segmentation works on the principle of discontinuity i.e. Edge based

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segmentation 'discriminates' the region based on the 'difference' in intensity levels. As a result the regions are obtained basically by 'dividing' the pixels.

Detecting edges include steps like noise filtering, edge identification and edge localization. Edges can be categorized into four different types as; step edge, ramp edge, ridge edge and roof edge based on intensity profile as shown in below diagram.

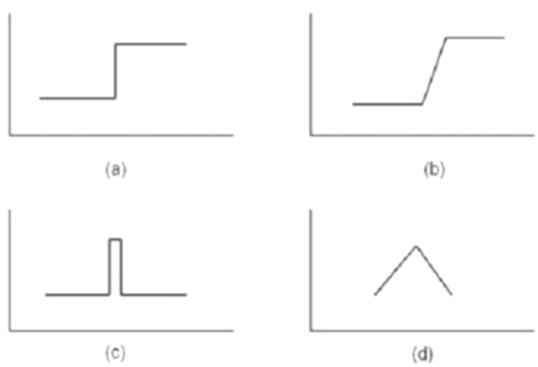

Fig.1 Intensity profiles of (a) Step edge model, (b) Ramp edge model,(c) Ridge edge model, (d) Roof edge model.

Step edge has very sharp intensity transition while ramp edge has slowly varying intensity variation, in these two types the intensity variation is between two different levels and transition back to original level is not compulsory. Ridge edge gives a short 'stay' time at the transited intensity level and after time is elapsed it comes back to initial intensity level, the rise and fall both happens sharply. Roof edge has slowly varying intensity profile; the rise and fall in intensity level is not drastic and is more practical type of edge in gray scale image models.

These edges can be identified using different operators and are broadly classified as first-derivative and second-derivative operators. The first derivative operators use gradients to find the edges in an image and the second derivative operators use Laplacians and local maxima of the gradients to find edges.

Among the available edge operators Sobel edge operator and Canny edge operator are widely used operators to extract the edges. While Sobel operator is first derivative operator, Canny edge operator is second derivative operator. The result of applying these two operators on an image is shown below. It can be seen that the Canny edge operator gives better number of edges.

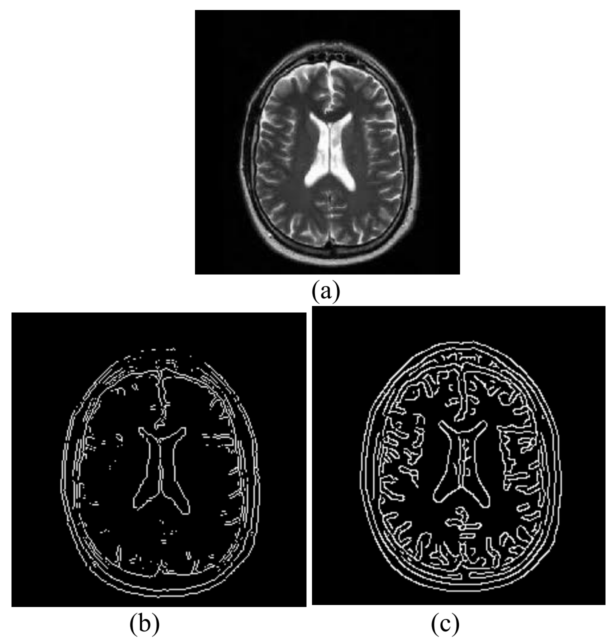

Fig.2 (a) Original image (b) Result of Sobel edge operator and (c) Result of Canny edge operator

III. REGION BASED SEGMENTATION

Region based method works on the principle of homogeneity to segment the image i.e. it 'treats' the pixels that belong to same region possess similar characteristics and vary only if it belongs to other region. These group of similar pixels can be obtained either by growing a region or by splitting and merging techniques.

As such region based method can be broadly classified as region growing method and split & merge methods.

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In region growing method a test pixel is considered, the test pixel first considers its neighbours that show similar characteristics and adds them to the test pixel and then checks the next neighbours and the process continues till the pixel under test exhibits diverse characteristic than the test pixel and the further growing of region in that direction is stopped. The test pixel is termed as seed. This method is in-out method i.e. it starts with one pel and then grows outwards until the dissimilarity exists between neighbours. Region growing method is widely used for its stable and reliable output.

Split & Merge method considers whole image as one region initially and then tests each pixels for the given condition. It is an iterative method which divides the image into four quadrants based on certain pre-defined criteria.
Each quadrant is further investigated for the defined criteria and is divided into further quadrants if the test results are negative. Splitting the quadrants is stopped when further division is not possible. This is represented in the following diagram.

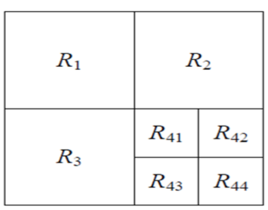

Fig 3 Region split & merge model

After obtaining the regions, if two neighbouring regions satisfy a given criteria then they are merged to form a single region. The split & merge method is out-in process where it starts with too many regions or an image as a whole and ends at small number of regions depending on the test condition specified.

Region based method is flexible to use as it provides user to choose between semi-automatic and fully automatic mode of applications. This method gives better result compared to other methods, if proper seed is selected. It also has a problem of stopping rule; to stop the region growing if dissimilar pixels are encountered in a particular direction and seed based approach is scan order dependent, this has significant effect on smaller regions .Since seed based method starts from single pixel and ends with a region the boundary extracted in this process is more clear than other methods.

The combination of the edge based and region based method results in watershed algorithm and is explained briefly in the next section.

IV. WATERSHED ALGORITHM

Watershed algorithm is a combination of edge, threshold and region based approaches to segment an image and to obtain more stable results. To understand this method, let us take an example of water flow over a catchment basin. Imagine that there are several regions that are interconnected with each other and also are floating over a water surface.

If the floating area is punched with a hole then water starts rising from underneath. Consider a region which is being filled with water due to hole, when the region is filled completely the water starts to flow to the neighbouring region and the process continues. If a dam is built to control the water flow between regions then the visible top layer of the dam gives the boundary of different attached regions.

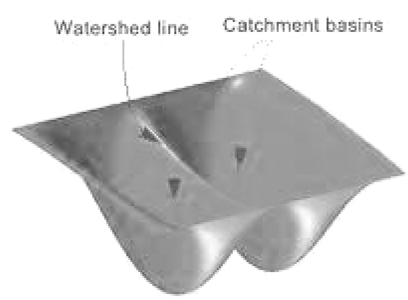

Fig. 4 Illustration of Watershed

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Extending this philosophy to images, the dams (boundary of region) are constructed using morphological process to control the flow of water (intensity levels). The local intensity level of regions are considered to construct the dam; when it seems that the neighbouring regions with nearly same intensity levels are about to merge, morphological operations like opening and/or closing are used to avoid unwanted merging between different regions.

Since the merging is to be restricted to within a single region it is better to have clear and distinct boundaries for object (regions). As a result the gradient of the image is calculated first to extract the required boundary of the object. The success of boundary extraction decides the number of watershed regions in the segmented output. Then the watershed algorithm is applied to extract the regions and finally the regions with similarity between neighbours are merged to reduce the ambiguity to identify regions. The algorithm to apply watershed transform is given below:

Step1:

The boundary values of the pixels of g(x,y) is to be found and the minimum value is to be assigned to M_i. Flooding is done by initializing n=min+1

Let $C_n(M_i)$ as the coordinates in the catchment basin associated with minimum Mi that are flooded at stage n.

Step2. Compute $C_n(M_i) = C(M_i) \cap T[n]$

$$\text{Cn(Mi)} = \begin{cases} 1 & for\ (x,y) \in C(Mi) and\ also\ (x,y) \in\ to\ T[n] \\ 0 & otherwise \end{cases}$$

let $C[n]$ denote the union of the flooded catchment basins at stage n:

$$\text{C}[\text{n}] = \bigcup_{i=1}^{R} \text{Cn(Mi)}$$

Set $n = n + 1$.

Step3. Derive the set of connected components in $T[n]$ denoting as Q. For each connected component $q \in Q[n]$, there are three conditions:

a. If $q \cap C[n-1]$is empty, connected component q is incorporated into $C[n - 1]$ to form $C[n]$ because it represents a new minimum is encountered.

b. If $q \cap C[n-1]$ contains one connected component of $C[n - 1]$, connected component q is incorporated into $C[n - 1]$ to form $C[n]$ because it means q lies within the catchment basin of some regional minimum.

c. If $q \cap C[n-1]$ contains more than one connected component of $C[n- 1]$, it represents all or part of a ridge separating two or more catchment basins is encountered so that we have to find the points of ridge(s) and set them as "dam".

Step4. Construct $C[n]$ using the values obtained for $C_n(M_i)$ and c[n] ;

Set $n = n + 1$.

Step5. Repeat Step 3 and 4 until n reaches max + 1.

The defined algorithm is the conventional flood based watershed transform. Despite of segmenting the region it often suffers over-segmentation; to avoid this we use markers.

Marker is bonded set of components that consists of pixel members belonging to foreground and background of an image. The foreground members are termed as internal markers and background members as external markers.

Markers are selected basically by defining a set of criteria that member to should satisfy. The criteria and its complexity to specify markers are subjective in nature and to test the condition hence defined, any segmentation approach can be used.

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V. Methodology

The proposed algorithm is basically the hybridization of several techniques that exists. To extract the abnormality in the biomedical image, the fundamental thing that is to be understood is that the abnormality has high frequency component which suggests that they are bright patches in a grey scale image. If these bright patches are picked up by processing system then it is helpful to understand and diagnose the abnormality. To extract these bright patches the following algorithm was implemented and the flow diagram is as follows:

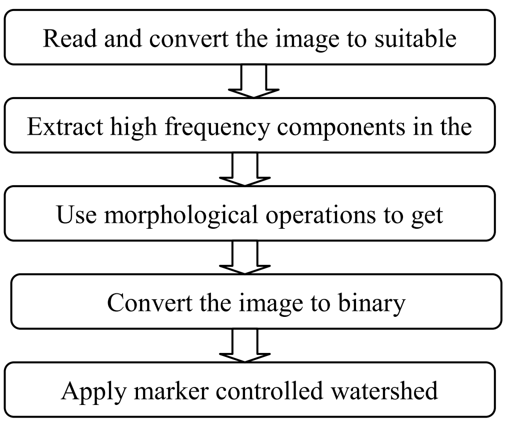


Fig 4. Proposed algorithm

First the image is to be converted to suitable grey scale image to process. Then suitable transformation can be used to extract high frequency components. To segment the regions, obtaining proper boundary is very critical and is obtained by using morphological operations, which are also used to reconstruct the image. The reconstructed image is to be modified to obtain thresholds so that we can apply watershed algorithm. Foreground and background markers are to be identified to avoid over segmentation. The watershed is then applied to segment regions in the image. The segmented regions can be displayed in colour to differentiate neighbouring regions.

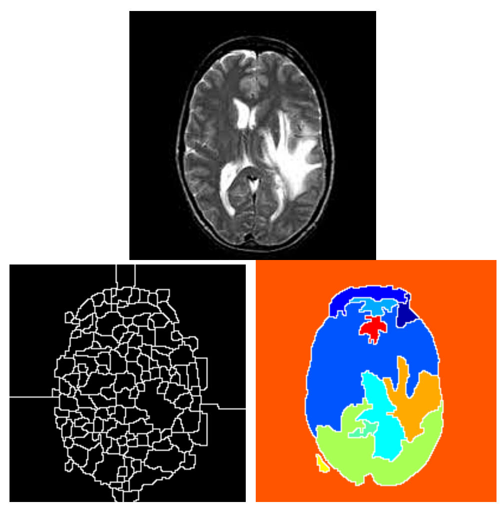
VI. Results and Discussion

The above discussed algorithm was implemented on few test images using MatLab2013a software on system Intel(R)Pentium(R)4CPU 2.80GHz 1Gb 32-bit OS and following results were obtained.

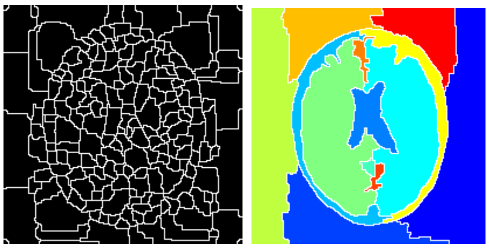
The following images (1) to (4) are to be read in the sequence

a. Original image

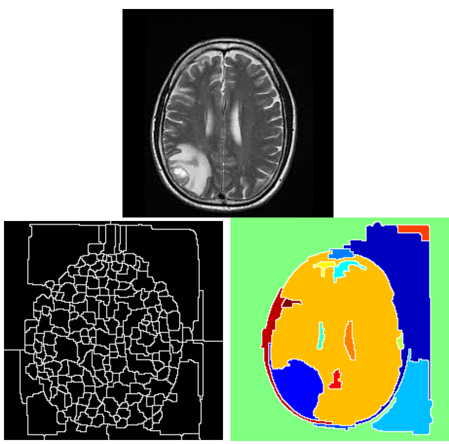
b. Conventional watershed c. Proposed algorithm



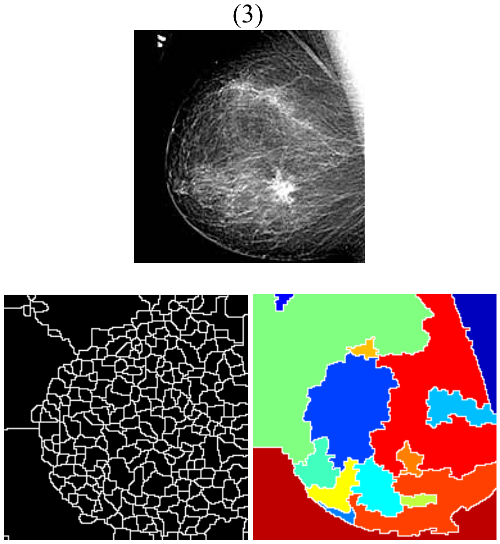
(1)



(2)



(3)



(4)

In the above figures the results of the proposed algorithm are shown. There are four different test images considered, among them three are MRI of brain and one is a mammogram image. The images are to be read as top single image is original image and the bottom left is the output of conventional watershed and the bottom right is the output of the proposed algorithm.

It can be observed that there is great reduction in the number of regions obtained after processing and hence we claim that our algorithm gives a solution towards to avoid over-segmentation, which is the chief drawback of conventional watershed algorithm. The shape of the regions is also maintained at its best to resemble original shapes.

To summarize, we have first extracted the high frequency components that corresponds to the possible abnormality of the considered organ. Then we performed morphological operations to reconstruct the filtered image and then modified it for thresholds to make it suitable before applying watershed algorithm.

VII. FUTURE WORKS

We also have observed that though there is considerable reduction in the over-segmentation, the obtained image is not ready-to-use for diagnosing as it can be observed in images that it suffers to mark the boundary between adjacent regions that vary slightly in the intensities. We are working on this minor problem to make the processed image ready to use at once the output is obtained.

VIII. ACKNOWLEDGMENT:

There is huge amount of literature available on the techniques and algorithms mentioned in this paper. The authors sincerely acknowledge all those who have contributed. If any reference or prominent names in this area of work are found to be missing in the citation list we acknowledge them also whole heartedly. We also express our gratitude to all the persons who were part of discussion to bring out this paper.

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