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Image Segmentation of Cranial Vault for Clinical Analysis

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Abstract: For several applications, segmented images gives better insight with increased accuracy and repeatability. Several segmentation algorithms were proposed for clinical purposes to diagnose, treatment and for tracking the progress of disease. Segmenting structures from medical images and reconstruction of specific anatomical shapes is difficult due to large size of datasets, complexity and variability of a given image. It is therefore, better to view the segmented images than the whole scan obtained from CT or MRI. Particularly, in surgical planning over diseased organ, segmented part is enough for visualization than the whole image. For example, if there is fracture in skull bone, it would be sufficient to view the fractured bone from a diagnostic image. Watershed segmentation is widely used in medical image processing applications because it is relatively fast in terms of computational time. An algorithm to segment the cranial vault bone based on Watershed method is presented. It is also implemented for few specific cranial vault abnormalities to demonstrate the results**.**

***Key words*:** Watershed; segmentation; cranial vault; MRI; Lesions

I. INTRODUCTION:

Medical imaging technologies for clinical analysis are developing rapidly and revolutionizing the medical field. The medical imaging allows visualizing and inspection of anatomic structures noninvasively into the body of the human by the physicians and scientists. Thus it helps for surgical planning, intra-operative navigation and for tracking the progress of disease. Analysis of images obtained from MRI, CT, and other modalities has become preoccupied with challenging problem of extracting required information with the assistance of computers and image processing algorithms for the clinical diagnosis and treatment of the disease [1] [2]. Although modern medical imaging devices provide exceptional images of internal organs, the use of computers to analyze and quantify the internal structures of the patient with accuracy and efficiency is limited. For the clinical diagnosis and life saving treatment, the quantitative data required to be extracted with greater accuracy and repeatability. Segmenting structures from medical images and reconstruction of specific anatomical shapes is difficult due to large size of datasets, complexity and variability of a given image. Another difficulty is that the shortcomings, while acquiring signal may cause discontinuity in boundaries affecting clarity of the structures in visualization. The challenge is to extract boundary elements of the structure from local information and integrate them to form the similar structure. At this stage of image processing expert intervention is required. Otherwise, incorrect assumptions due to misinterpretation of dataset may effect on qualified treatment plans.

The cranial vault or cranial base is the inside of the cranial cavity that supports the brain and associated structures [3]. It is the curvature of the skull bone that covers the upper and outer surface of the brain. The cranial bones gives protection to the brain and along with the skull bones, excluding mandible bone, provides stability to the head. Broadly, the deformability, tumors, swelling, lesions and fractures of the skull vault bones abnormality are diagnosed by CT or MR imaging in hospitals. Radiologists prefer CT (computed Tomography) and MR imaging (Magnetic Resonance imaging) to scan head, but most of the findings from the scans do not exhibit distinctive imaging features in several cases [4][5][6]. Another major difficulty of segmentation of medical images is the high variability in the images [7]. Radiologists investigate these images for the diagnosis and treatment of abnormalities. However, segmenting the skull vault bones from the scans by image processing methods increases accuracy and repeatability, in turn, assisting the physiologists in the planning of their treatment.

In this article, a computer based watershed segmentation algorithm for image analysis is presented with few cases of cranial vault abnormalities.

II. BACKGROUND

Image segmentation may be described as the partitioning of an image into non-overlapping, constituent regions that are homogeneous with respect to some characteristics [8]. The procedure is one of the most critical and challenging task of image processing. It has various applications over a wide spectrum ranging from vehicle's number plate identification in traffic management to the cancer cell detection in clinical investigations. Several image segmentation techniques are available in literature, but there is no common method which can be considered good for all images [7]. As the number of

algorithms developed is increasing each year continuously [9], it is considered as a great challenge by the computer vision researchers. Very popular image segmentation techniques that are still used today by the researchers are edge based [10], region based [11], histogram based [12], threshold based [13], model based, feature based and Watershed transformation which can be found in literature. Segmentation of medical images is relatively difficult but important part of image processing, thus become focus of attraction for the researchers from various fields.

Human body comprised of different organs and each organ consists of biological components such as bones, tissues and blood vessels. Each component of any organ can influence the health condition of the person. Medical images display the organs spatially by non-invasive method to view them for the characterization. X-ray CT and MRI are most widely used radiographic imaging techniques for clinical purposes. The scans from these systems are referred for quantification of tissue volumes, diagnosis, pathology, anatomical and functional information. Every scan of images differs in noise level, artifacts contrast and resolution when it is focused for a particular organ. For example, the most intricate, complicated and impressive organ is the brain which has different sections and is protected by the skull vault bones. Several research articles have been reported in the area of brain image segmentation for tumors, brain tissues (such as white matter, gray matter) and CSF (cerebrospinal fluid) from medical images based on various algorithms. It is equally an important objective to consider cranial bones for segmentation which could help to understand the pathological changes in various forms of degenerative brain diseases. Therefore, in this work the cranial vault bone segmentation from Watershed algorithm is proposed which could assist in clinical analysis of medical images enhancing accuracy and repeatability.

III. METHODOLOGY

The human head mainly consists of brain, cranial vault and the skull bone. The cranial vault formed by the frontal, parietal, occipital and temporal bones, and the greater wings of the sphenoid bone. Below figures (Fig 1) shows the sagittal section of a human skull with cranial vault.

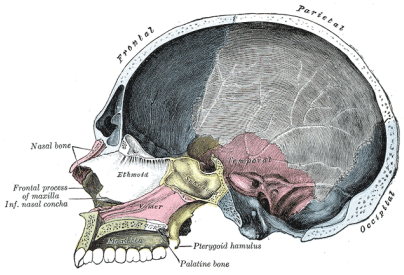


Fig. 1 Sagittal section of a human skull with cranial vault *(Gray's Anatomy)*

In humans, the cranial vault is imperfectly composed in newborns which remain quite plastic as the brain grows in childhood and the plasticity loses as the fontanelles close. The shape of the head can be altered artificially by tightly binding with cloth or other material during infancy, which is being done either for aesthetic or religious reasons [14]. There could be deformity due to few acquired abnormalities. Few acquired abnormalities in cranial vault of human head are explained below.

Cranial vault fractures: The majority of head trauma involve the cranial vault. The cranial vault injury could be due to fractures in the frontal or parietal bone. It can be depressed, closed, or open with or without involving the brain.

The most common lesions of the cranial vault, such as epidermoid, dermoid, and isolated eosinophilic granuloma, are benign. The majority of skull tumors are present as an enlarging mass which appear as swelling over the skull.

In several instances, surgical procedures are to be carried to reshape or remodel the bones of the skull to expand and enlarge the space within the vault for restoration natural appearance of the skull shape allowing the normal growth of brain within it.

In above all cases, the surgeon will prepare the plan for surgery by viewing the medical images scanned for the purpose. Image segmentation of these bones from the scans could help the surgeon in the procedure. The segmentation of images by watershed method for implementing on MR images explained in the following.

Watershed Algorithm

Principle

The principle of watershed transform suggests that any greytone image can be considered as a topographic surface. If this surface is flooded from its minima, and if the merging of water coming from different sources, similar to that water flowing from catchment area in a lake, then the image can be portioned into two different sets as the catchment basins and the watershed lines. For better understanding, one can imagine that the bird view over a large water source accumulating behind a storage dam. Suppose the transformation is applied to the image gradient, the catchment basins then theoretically correspond to the homogeneous grey level regions in the image. If a drop of water flowing the gradient of an image then, that drop flows a path through ultimately reach a local minimum. That means, by nature, the fluidic water always flows into the lower basin. In simple words, it is the line which determines

where the drop of water will fall into the region. This classic algorithm was introduced by Luc Vincent and Pierre Soille [15], which was based on the concept of "immersion". This algorithm is particularly useful for segmenting objects that are touching one another. Initially, the concept was used by Digabel [19] which was later reviewed and implemented efficiently by Vincet [15][16]. The morphological watersheds provide a complementary approach to the segmentation of objects. It is useful in particular, for segmenting the objects which are touching each other. This algorithm being applied for medical image segmentation by various researchers [17][18].

Proposed Work

For implementing the watershed algorithm, generally, three methods are followed; distance transform approach, the gradient method and the marker controlled approach.

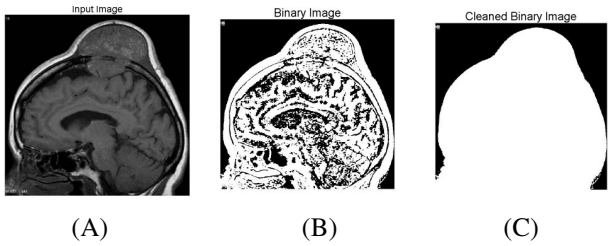
In the distance transform approach, the distance from every pixel to the nearest non-zero valued pixel is calculated. This is the first step of pre-processing the image before implementing the watershed algorithm. Important steps of the proposed work are shown below. In this work, T1 weighted MRI scans of the head and brain from the web source are taken as input images. To implement the algorithm, the computer program is written and executed in Matlab Software. Each step of the program is explained in detail in the following paragraphs.

- Load input image
- Pre-processing and threshold
- Conversion to binary image
- Apply Watershed
- Output image

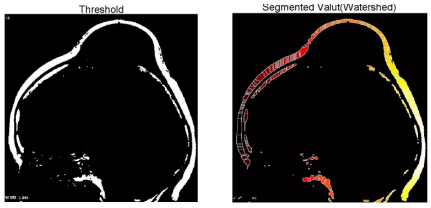
The MRI scan of the brain with skull bone is considered as original input image. It is loaded in Matlab platform to read as input image for implementation of Watershed algorithm. Most of the medical images have inherent noise and with different contrast levels. They are pre-processed to remove the noise. This is carried out by subtraction of opened image from the original image. Then the correct level of threshold is calculated for a value by which the skull bone can be segmented. By thresholding the image at this value, it is then converted to binary and its inversion form. For the binary image, distance is calculated all the nearest non-zero values are pushed within the image. The purpose of doing this step is to force the local minima inside the image to facilitate the water filling within it, hence to apply the watershed. Finally, watershed is applied such that all the ridges are given zeros and the catchment basins with non-zeros.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

MRI scans of the cranial vault with brain are taken as input images. In order to simplify medical terminology, each scan with specific abnormality is referred as 'Lesion 1', Lesion 2' and Lesion 3' in general for demonstration of algorithm. Each scan is from sagittal section with distinct abnormality evident from the scan. For every lesion as an input image (A), the binary image (B), cleaned image (C), thresholded image (D) and segmented image (E) are shown in the below Fig.2, Fig.3 and Fig. 4. These are the results of each step implemented through this algorithm.

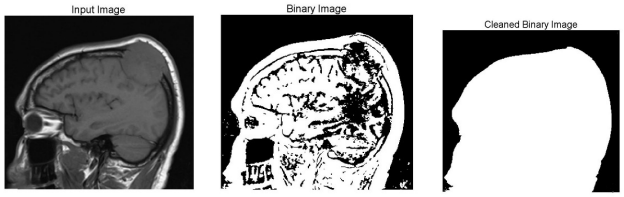


(A) (B) (C)

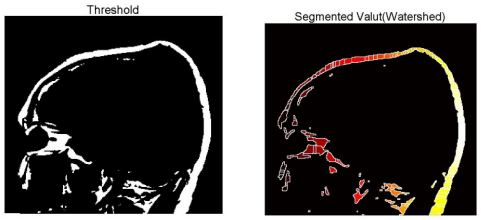


(D) (E)

Fig. 2 Segmentation for 'Lesion 1'

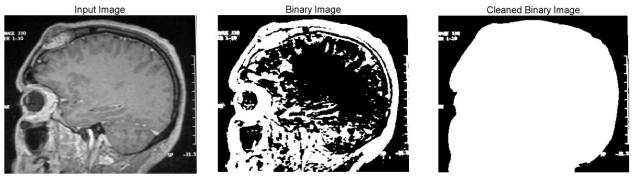


(A) (B) (C)

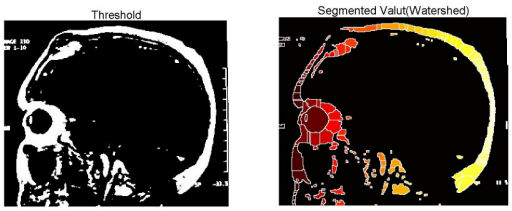


(D) (E)

Fig. 3 Segmentation for 'Lesion 2'



(A) (B) (C)



(D) (E)

Fig. 4 Segmentation for Lesion 3

Analysis of calvarial bone is a pathophysiological procedure which is normally done in radiographic images. Their evaluation is essential for the patients with cranial vault lesions [20], calvarial vault bone fractures [21] and cranial vault remodeling [22][23]. In these cases the evaluation is carried out directly on MRI/CT scans. But, it would be better to do the analysis in the computer with the image processing tools. Computer based image analysis techniques are attracting researchers due to their software capabilities. The proposed image segmentation is fast and easy to implement that may help for the related diagnosis as well as post-operative patients to plan for future course of treatments. While implementing the method, care should be taken against over-segmentation which can be accomplished by selecting suitable values in the programming.

V. CONCLUSION

Segmentation for image analysis has its own significant imprint in medical imaging. Watershed method of segmentation is being used for various applications in digital image processing. The methodology is explained in steps and demonstrated on MR images. Segmented images of cranial vault bone obtained in this work could be useful for surgeons or radiologists. After scanning procedure, the image analysis can be performed as and when required. There will be scope to evaluate precisely by changing parameters, if required, for better treatment plans.

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