

Outer contour extraction of skull from CT scan images

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Abstract. Extraction of the outer contour of the skull is an important step in craniofacial reconstruction. The outer contour is required for surface reconstruction of the skull. In this paper, we propose a method to extract the outer contour of the skull. The extraction process consists of four stages: defining the region of interest, segmentation of the bone, noise removal and extraction of the outer contour based on scanning from the four sides of the image. The proposed method successfully extracts the outermost contour of the skull and avoids redundant data.

1. Introduction

Extraction of the outer contour of the skull is an important step in craniofacial reconstruction [1], [2]. This step is performed before the surface reconstruction to build a 3D model of the head. By finding the contours of the skull, we can perform a contour-based surface reconstruction, which is one classical method of surface rendering that has been developed since 1975 [3] and continues to grow to this day. According to Kumar [4], contour-based surface rendering algorithm is efficient and it reduces the search space, also it decreases the computation cost. This method is simple, easy for calculation and much classical [5].

Contour extraction for surface reconstruction of the skull has its own challenges. On the one hand we have to find the most important contour, but on the other side, the skull structure is very complex. The skull can be divided into two portions: neural and facial. The neural skull is made up of 6 bones: frontal, parietal, temporal, occipital, sphenoid and ethmoid. The facial skull comprises 8 different bones: mandible, maxilla, palatine, zygomatic, nasal, lacrimal, vomer and inferior nasal concha [12]. This complexity make possible to obtain redundant data. Hence it is very important to find the right method so that the contours of the skull can be detected properly without containing a lot of redundant data. In this paper, we propose a method for extracting the outer contours of the skull based on the scanning from the four sides of the image.

2. Related Work

Several studies to extract the contours of the skull been done before. In general, based on the results of the final contour, the detection of the outer contour of the skull can be divided into two, first, methods that detect the outer contour by closing the holes and hollows. The results of these methods are a



closed contour. Second, methods that detects the contours of the skull without closing the holes and hollows, so some holes left open. In some parts, the resulting contours are not connected.

In a study [2], active curve is used to extract the contour. The active curve has three forces called extraction force, adhesion force and regularization force. Contours produced from this method are in the form of a single closed contour by filling the holes and hollows that exist in the skull boundary. Curve evolution is used in [6]. The curve used three factors to evolve. These factors named attraction force, adhesive force and regularization force. This research resulted in a single closed contour. The holes or hollows of the skull were closed by the curve. In other study [7], newborn CT images were segmented using coupled level set to detect the inner and the outer contour of the skull. The segmentation results were compared with manual segmentation. The proposed method provided satisfactory result. All of these methods [2], [6], [7], produced a single closed contour, making it less suitable for contour extraction in the part of skull with holes and hollows. Extra contours are added to the holes and hollows, resulting in redundant data.

In a study [8], three steps were performed to extract the outer contour of the skull. The first step was finding contour points using Sobel operator, then a circular scanning was implemented, and then followed by an 8-neighborhood boundary tracing. The results of this study were the outer contour by keeping the holes and hollows. In this method, the user must determine the threshold value which defines the outer contour distance from the center of the image. The threshold usually defined as half of the maximal distance from the skull to the center and the rest must be defined by user manually. This creates difficulties when user works with a lot of data.

The proposed method is designed to avoid redundant data, while minimizing human intervention to the system.

3. Method

The data used in this research is CT scan images of the head of three patients. All data is the result of CT scan of complete head. Data is stored in DICOM format. Each record consists of approximately 300 slices with a size of 512x512 pixels. These slices cut the head in a horizontal position. Thus the CT image we got is a piece of the head when viewed from the top or bottom.

Broadly speaking, the contour extraction method we are proposing consists of 4 stages, namely a) defining the region of interest, b) segmentation of the bone, c) noise removal and d) extraction of the outer contour. Figure 1 shows all the stages of the proposed method.

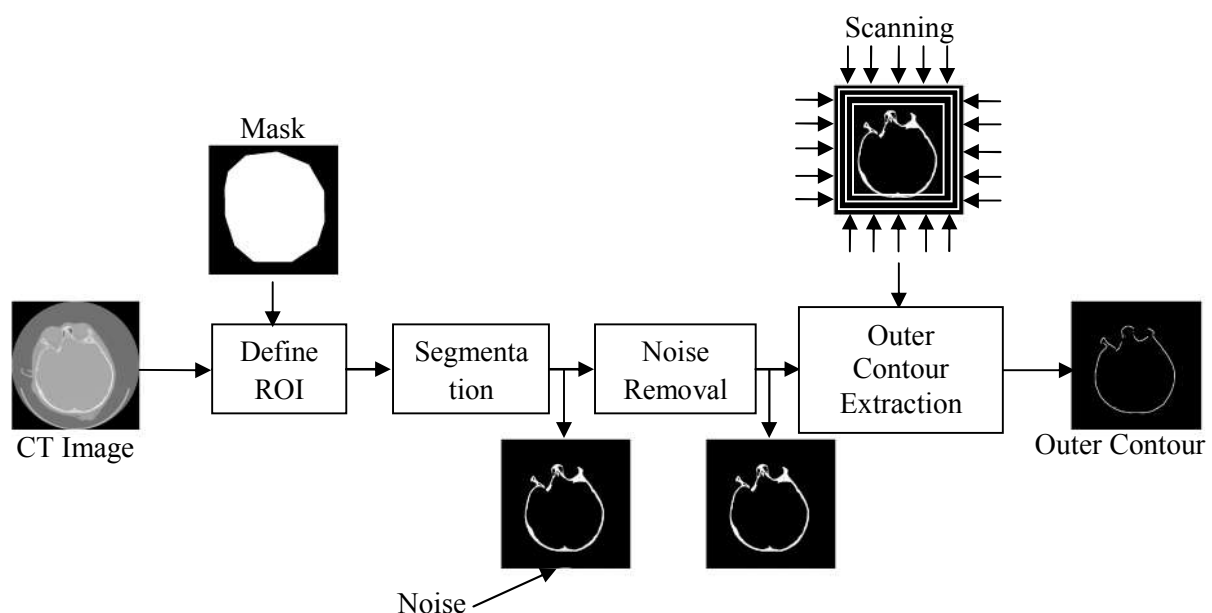


Figure 1. Block Diagram of The Method

The outer contour extraction process is performed per slice. CT scan image is composed of several sections. The part that we want for further analysis is the head. The position of the head is located in the center of the image. To focus on the processing of the head, then we set the center of the image as a region of interest (ROI). Defining ROI is done by a polygon mask which surrounds the head. Polygon mask is in the form of a binary image with a size of 512x512 pixels. Pixels values inside the ROI are 1 and the outside the ROI are 0. This mask works like scissors that cut the part outside of the ROI. By specifying the ROI, then the non-ROI located at the side of the image will be ignored in the subsequent analysis.

If we observe each slice on CT images, the skull bone is brighter than the other regions. In other words, the bone has the highest intensity compared with other regions. Under these conditions, the segmentation of the skull can be done by thresholding. Based on observations of pixel intensity values, the bone has a value of more than 0.8 (pixel values is normalized). Therefore, this value is used as the threshold value. With a fairly high threshold value, only the bones are taken.

Results of segmentation are binary images with pixels values 1 for foreground and 0 for background. It still contains a little noise in the background. This section is obviously not part of the skull because it is located at the lower end of the image. This noise disturbs the contour extraction process, so it must be eliminated. Noise removal can be done easily because the location of the noise can be known with certainty. The noise is removed by replacing the pixels values become equal to the value of the background.

The next stage is to extract the outer contour of the skull. The outer contour is defined as parts of the skull that can be seen from the four sides of the image. Extraction is done by scanning the outer contour starting from the left, right, top and bottom of the image. The scanning process is done in the horizontal direction from the left and right sides, and in the vertical direction from the top and bottom sides. Thus, the number of pixels on the scanning results from left and right sides are the same. Likewise, the number of pixels on the scanning results from the top and bottom. The scanning process is done to find the foreground. Scanning was stopped after the first foreground point is found. The first foreground is the first pixel with value=1 that found in the scanning process. Thus the line which is considered as the outer contour is the entire first foreground pixels resulted in the scanning process.

Results of the outer contour extraction are then compared with the results of contour extraction using Gradient Vector Flow (GVF) snake [9] and Canny Edge Detection [10]. GVF counted 100 iterations by giving a value of $\mu=0.2$. Weights of the snake's internal forces are set at 0.01 to elasticity parameter (α), 3 for rigidity parameter (β) and 1 for the viscosity parameter (γ). Whereas the weight of the external force (κ) was set equal to 2. The initial contour of each slice is the convex hull of the skull bone. Snake deformations performed a total of 250 iterations. Canny Edge Detection is chose because its algorithm performs better than many other operators [11].

4. Result and Discussion

The process of the outer contour extraction of the skull has been successful. The input images are slices of head CT scan with a size of 512x512 pixels. Determination of the region of interest have been successfully separated the image that are not needed in the analysis. Only the head is used for further analysis.

The segmentation separates the bones from the head. The bones are composed of several parts. At slice 1 to slice 89 there are portions of the spine. The bones at slice 90 to 180 shaped like a circle with some breaks. Meanwhile, the shape of the bones at slice 181 to 306 are almost a circle without breaks.

Segmentation is performed by thresholding. It produces noise at the bottom of the image. The noise is very disturbing and must be eliminated. Fortunately the noise position can be known with certainty. From observation, the noise lies at the bottom of the image on the line 510 up to 512. Thus, the pixel values of the lines are converted to 0. Finally, we obtain the skull bone without noise.

After segmentation, outer contour scanning is performed. Visually, the scanning results for slice 1 to slice 180 seem to disconnect some parts of the skull. In the segmentation result, these parts are connected properly. However, because what we want is the outermost contour, the disconnected parts

are the best result because the parts will not be visible when viewed from the outside. These parts can be referred to as redundant data. By eliminating redundant data, contour data become smaller and easy to compute.

For slice 181 and the next, contour extraction results are in the form of a single closed contour without disconnected parts. This occurs because the bone structure is approaching a circle, so that no part is lost when viewed from four sides of the image. The extraction process succeeded in eliminating the contours inside the skull. Results of the outer contour extraction process are shown in figure 2.

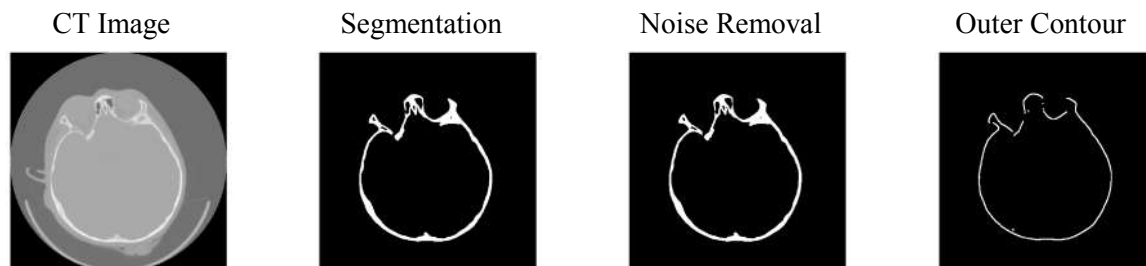


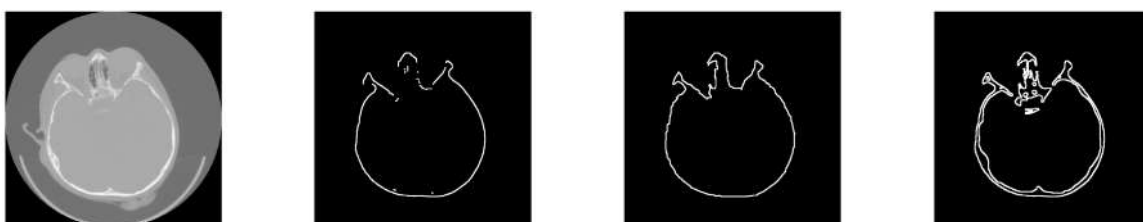
Figure 2. Result of Contour Extraction Process

The outer contour extraction results compared to two other methods, GVF Snake and Canny Edge Detection. From visual observations can be seen that the contours produced by GVF Snake are in the form of a single closed contour by adding contours on some parts that should be disconnected. Results of Canny Edge Detection include the contour inside the skull. While the proposed method managed to get the contour without adding parts that should be disconnected and also eliminates the contour inside the skull. Figure 3 shows the visual differences between the three methods.

Slice 200



Slice 150



Slice 50



Figure 3. Visual Differences. From left to right: Our method, GVF Snake, Canny Edge Detection

Judging from the thickness of the contours obtained, the proposed method successfully extracts the contour with a thickness of one pixel in all parts. GVF Snake and Canny Edge Detection also detects contour with a thickness of one pixel, but in some parts of the contour, it has a thickness of two pixels. This happens on sloping inclined contour line (instead of vertical or horizontal). In this case, the measurement of the thickness contours conducted in vertical or horizontal direction.

In terms of the number of pixels, the proposed method generates contour with a small number of pixels. It is smaller than pixels extracted by Canny Edge Detection. Thus it can be said that the proposed method only took required pixels. The method managed to eliminate many redundant data that is not needed. But in many slices GVF Snake extract smaller number of pixels. This happens because GVF Snake disconnects some parts of the contour extracted. In fact, this contour should be connected. This case does not happen on the Canny Edge Detection and our method; all contours obtained are connected properly. Figure 4 shows the pixel observation of the three methods. Comparison of the results of contour extraction by the three methods is shown in table 1.



Figure 4. Result of Pixels Observation

Table 1. Comparison of The Methods

Object of Observation	Our method	GVF Snake	Canny Edge Detection
Single contour	Yes	Yes	No
Added contour	No	Yes	No
Redundant contour	No	Yes	Yes
Two pixel contour thickness	No	Yes	Yes
Cut off	No	Yes	No
Number of pixels extracted :			
Slice 250	874	853	2353
Slice 200	978	942	2696
Slice 150	997	1239	3355
Slice 50	567	659	1474

5. Conclusion

We have presented a method for extracting the outer contour of the skull of a CT scan of the head. Contour extraction process begins by selecting a region of interests, followed by segmenting the bones using a thresholding technique. This was followed by noise removal and ends with the extraction of the outer contour. The proposed method has several advantages compared with GVF Snake and Canny Edge Detection. The proposed method avoids adding extra contour, eliminates redundant contours inside the skull and generates contour with a thickness of one pixel. In this case, it can be said that the

proposed method is better than GVF Snake and Canny Edge Detection. In the next research we will reconstruct the skull surface based on the contours extracted.

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