Analysis of Medical X-ray Bone Images Using Image Segmentation

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Abstract Image enhancement is the preprocessing stage of the image processing. The objective is to improve the visual effects and the perception of knowledge in images for viewers and to provide a better input for automated image processing technique. It gives emphasis on the whole or part features of the graphics in the designated image applications to enlarge the objects in the graphics. The enhanced image by use of threshold segmentation method identifies bone fracture in medical X-ray images. In this research work, the image is taken as input, and after noise removal, the X-ray image of right hand and hairline bone fracture image are being segmented using simple thresholding, multiple thresholding, and optimal thresholding method and they are compared with each other so as to choose the best technique for threshold image segmentation.

Keywords Medical image · X-ray · Segmentation · Thresholding

1 Introduction

In recent years, many efforts have been taken in developing automatize systems in the area of biomedical and bioinformatics applications. Medical image processing is one of the research areas with an interdisciplinary character that has dramatically grown in recent decades, and it has a large application domain for redundant

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clinical problems [1]. It sums up expertise from multiple disciplines such as computer sciences, engineering, mathematics, statistics, and medicine. For some applications such as image enhancement and compression, we cannot process the whole image at a time. Therefore, several image segmentation algorithms are being introduced. Image enhancement is the preprocessing stage for image segmentation, and the aim is to enhance the visual effect of the image by noise removal. Image segmentation is the process of partitioning a digital image into multiple clusters or super pixels according to the attributes of the image [2, 3]. Actually, the segments (clusters) are different objects in image which have the same color. Image segmentation results with a set of regions or sections that collectively cover the whole image. In a region (cluster), all of the pixels are similar with respect to some characteristic or computed property, such as intensity, color, or texture. The adjacent regions are significantly different with respect to the same characteristics. The main goal of medical image segmentation is to extract clinically relevant information or knowledge such as fractures present in bone X-ray images. Medical imaging focuses on the computational analysis of the images, not their acquisition [2]. Fracture detection based on image classification is an area of research which has proved to be challenging for the past several decades. This field has gained more importance due to the new challenges got by voluminous image databases. In medical imaging, the different segments often referred to different tissue classes, living organs, pathologies, or other biologically relevant forms. Medical image segmentation is made difficult due to low contrast, noise, and other imaging ambiguities [4]. Image segmentation is basically used to locate objects and boundaries of interest in images [5]. Basically, the segmentation method is divided into three categories as mentioned in Fig. 1 given below.

In our paper, we have used threshold-based image segmentation method for implementation. Thresholding is a simple approach used for image segmentation, where we need to fix a threshold value, and the output of thresholding is an image represented as groups of pixels with values greater or equal to the threshold or value less to threshold value [6]. The main objective of X-ray bone image segmentation is to subdivide the various portions of the image, so that it can help medical practitioners during the study of bone structure, identification of bone fracture, measurement of fracture treatment, and treatment planning prior to surgery. It has been considered as a challenging task because the bone X-ray images are complex in nature and the output of segmentation algorithm is affected due to various factors such as presence of noise and artifacts.

Goal of the paper: The goal is to analyze medical X-ray images through thresholding methods for medical imaging applications. For analysis of X-ray bone images, different thresholding methods are being used and the results are compared with each other. The general thresholding techniques used in our research are simple thresholding with different thresholding values, multiple thresholding, and optimal thresholding. The segmentation generates an enhanced image using intensity-based segmentation on the X-ray image.

Paper outline: The contents of the paper are organized as follows: In Sect. 2, the description of the thresholding-based segmentation method such as simple, multiple, and optimal thresholding are briefly discussed; in Sect. 3, the experimental results are presented and discussed; and conclusion is given in Sect. 4.

2 Thresholding-Based Segmentation

The threshold technique is the most widely used and the simplest technique to segment an image. Thresholding technique is basically used for segmenting image, having bright object on a dark background. It is useful in discriminating foreground from the background or object and background. According to Sezgin and Sankur, thresholding method is classified into the following categories:

1. Histogram-shape based
2. Clustering method
3. Entropy-based method
4. Object-attribute method
5. Spatial method
6. Local method

Generally, digital images are viewed as a 2D matrix or 2 variables function consisting of discrete points called pixels. There is a measure difference between a gray-level image and color images in the range of pixel counts. In image processing, it is simple to take a gray-level image in comparison with color image. In clustering method of thresholding, the gray-level samples are clustered into two parts such as foreground and background. For simplicity, the gray-level image is converted to a binary image. By selecting an adequate threshold value T, the binary image can be created by converting gray-level image [1, 7]. The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. The most widely used way to convert a gray-level image to a binary image is to select a single threshold value (T). Then, all the gray-level values below T are treated as background and above T are considered to be the part of the object. The color code of the background is black (1), and the foreground color is white (0). The segmentation problem becomes one of selecting the proper value for the threshold T. Threshold technique can be expressed in the equation form given below.

$$T = T[x,\ y,\ m(x,\ y),\ n(x,\ y)] \tag{1}$$

T is the threshold value, where x and y are the coordinates of the threshold value point, $m(x, y)$, $n(x, y)$ are points of the gray-level image pixels. Threshold image $f(x, y)$ can be defined as:

$$f(x,y) = \begin{cases} 1 & \text{if } f(x,y) > T \\ 0 & \text{if } f(x,y) \le T \end{cases} \quad (2)$$

In many types of images, the gray values of an object are different from the background value and thresholding is many a time a well-suited method to segment an image into objects and background. If the objects are without overlapping, then we can make a separate segment from each object on the threshold binary image, thus assigning a unique pixel value to each object. Many methods exist to select a suitable threshold value for a segmentation task. The simplest method is to set the threshold value interactively; the user manipulating the value and reviewing the thresholding result until a satisfying segmentation has been obtained. The histogram is generally a valuable tool in establishing a suitable threshold value.

2.1 Multiple Thresholding

Threshold-based algorithms are divided into single and multiple thresholding categories. Multiple thresholding approach focuses on finding multiple thresholds which aims to separate multiple objects. When several desired segments in an image are introduced, then threshold segmentation can be extended to use multiple thresholds to segment an image into more than two segments: All pixels with a value lesser than the first threshold are assigned to segment number 0, all pixels with values between the first and second threshold are assigned to segment number 1, all pixels with values between the second and third threshold are assigned to segment 2, etc. If n thresholds ($t1$, $t2$ … tn) are used,

$$f(v) = \begin{cases} 0 & \text{if } \quad v < t1 \\ 1 & \text{if } t1 \le v < t2 \\ 2 & \text{if } t2 \le v < t3 \\ : & : \quad : \\ n & \text{if } \quad tn \le v \end{cases} . \quad (3)$$

After thresholding, the existing image has been segmented into $n + 1$ distinct segments identified by the gray values 0 to n, respectively.

2.2 Optimal Thresholding

Optimal thresholding is applied where the histogram is the sum of two overlapping distributions. It is a technique that approximates the histogram using a weighted sum of distribution functions. The distribution function sets a threshold in such a way that the number of incorrectly segmented pixels (as predicted from the approximation) is minimal. In optimal thresholding, a criterion function is devised that yields some measure of separation between regions. A criterion function is applied for the intensity and that which maximizes this function is chosen as the threshold.

3 Results and Discussions

The threshold segmentation was implemented using (MATLAB R2010a, 7.4a), and the segmentation techniques are tested on the two images illustrated in the Fig. 2. Three techniques are applied on these images such as simple thresholding, multiple thresholding, and optimal thresholding techniques.

3.1 Simulation Results

Figure 1 showing the classification of Image Segmentation.

These are various results obtained by thresholding through implementation on an image of X-ray showing right hand (Figs. 3 and 4, Table 1).

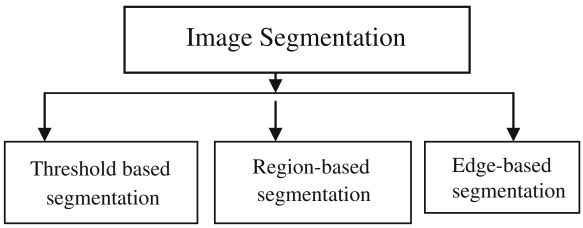

Fig. 1 Model for classification of image segmentation

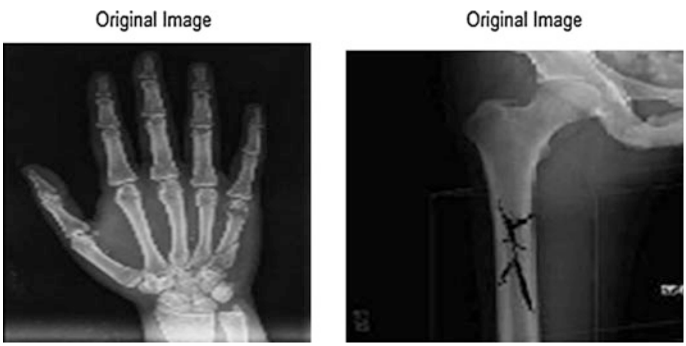

Fig. 2 The original images of *right hand* and hairline bone fracture

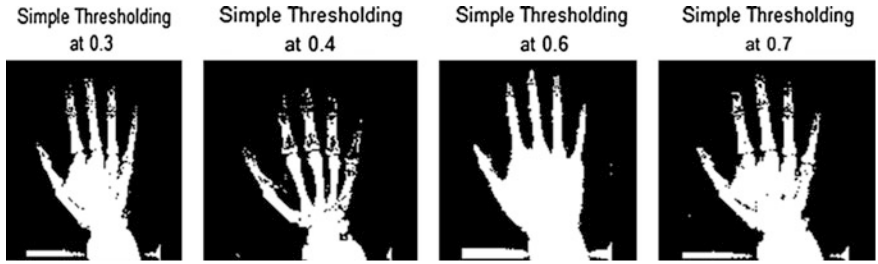

Fig. 3 Simple thresholding on original *right hand* image at 0.3, 0.4, 0.6, and 0.7 thresholding

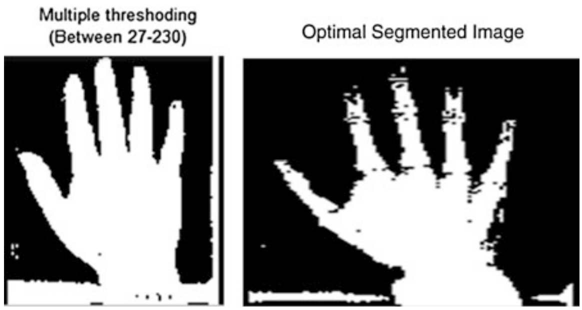

Fig. 4 Multiple thresholding (between 27 and 30) and optimal segmentation of original image

Table 1 Table shows size of the image after and before simple thresholding for X-ray hand image

Sl. no.	Name	Size	Bytes	Class attribute
1	X-ray hand image original	881 × 750 × 3	1,982,250	Unit 8
2	X-ray hand image at threshold 0.3	881 × 750	620,450	Logical
3	X-ray hand image at threshold 0.4	881 × 750	573,521	Logical
4	X-ray hand image at threshold 0.6	881 × 750	660,750	Logical
5	X-ray hand image at threshold 0.7	881 × 750	633,427	Logical

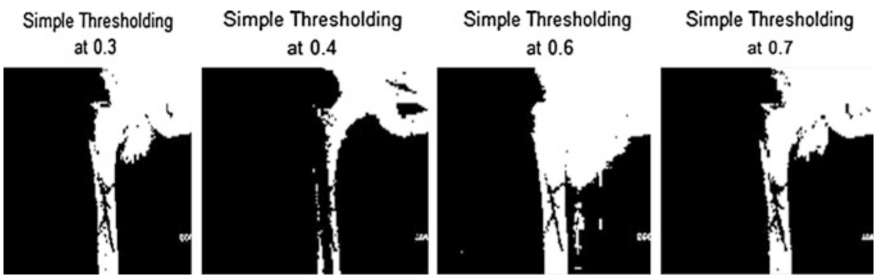

Fig. 5 Simple thresholding on original hairline bone fracture image at 0.3, 0.4, 0.6, and 0.7 thresholding

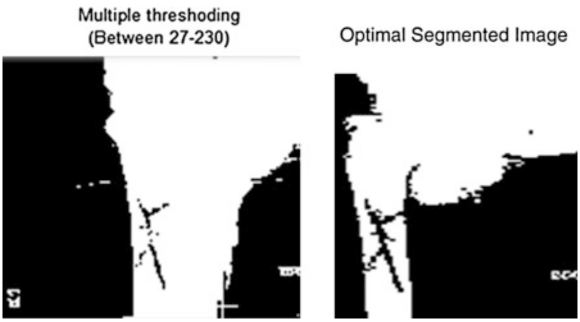

Fig. 6 Multiple thresholding (between 27 and 30) and optimal segmentation of original image

Table 2 Table shows size of the image after and before simple thresholding for X-ray hairline bone fracture image

Sl. no.	Name	Size	Bytes	Class attribute
1	X-ray hand image original	881 × 750 × 3	1,982,250	Unit 8
2	X-ray hand image at threshold 0.3	881 × 750	620,450	Logical
3	X-ray hand image at threshold 0.4	881 × 750	573,521	Logical
4	X-ray hand image at threshold 0.6	881 × 750	660,750	Logical
5	X-ray hand image at threshold 0.7	881 × 750	633,427	Logical

Various results obtained by thresholding through implementation on an image of X-ray showing hairline bone fracture (Figs. 5 and 6, Table 2).

4 Conclusion

In this paper, the effectiveness of the simple thresholding techniques at different levels, multiple thresholdings, and optimal thresholdings are compared to medical images. In our paper, we have taken 2 medical X-ray images one without fracture and another with fracture, after applying different segmentation techniques discussed above, in hand X-ray image with simple thresholding at 0.4 threshold value it is separating the object and background in a proper way but for hair line fracture image the fracture is clearly visible with optimal thresholding. From this, we can analyze that the efficiency of different segmentation algorithms are dependable on type of images.

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