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EFFECTS OF DIFFERENT STRUCTURING ELEMENTS IN 3D SEGMENTATION OF LEFT-CORONARY ARTERIES USING CT IMAGES

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Coronary heart diseases are one of the most prevalent causes of deaths not only in Bangladesh but also all over the world. 3D segmentation of arteries of heart plays an important role for the analysis of coronary heart diseases. It also helps the physicians to take perfect decision for treatment and surgery procedure. Morphological operators play an important role for segmentation of the object shape in medical image processing. Morphological operators use the structuring elements for image processing. In this paper we have implemented the effects of six structuring elements for segmentation of CT images of coronary arteries of heart. It shows that different structuring elements have significant effects for segmenting the arteries and processing time.

Keywords: Structuring element, Morphology operators, Segmentation, Coronary artery, CT.

Introduction. Coronary heart diseases (CHD) are the most prevalent causes of death not only in Bangladesh but also all over the world [1]. It is also called silent killer. Narrowing (stenosis) or complete occlusion of the arteries of the heart causes serious condition such as heart attacks and strokes. Noninvasive imaging technique such as computed tomography (CT) has greatly assisted the diagnosis of coronary heart diseases of the patients. It is laborious to analyses these images manually [2]. Vessels are indeed 3D anatomical structures. So the accurate segmentation and visualization of 3D anatomical structure is also very important so that physicians can take accurate decision for treatment.

Morphology relates to the study of object forms or shapes. It facilitates the segmentation and search for object of interest by filing holes and eliminating unwanted segments [3]. Morphological image processing is based on the idea of probing an image with a small shape or template known as a structuring element. The structuring element is positioned at all possible locations in the image and certain operation is performed according to the relation between image content and the structuring element [4, 5]. It is possible to use structuring element of different shapes to perform a specific task. This paper investigates structural element of different shapes in the 3D segmentation of left coronary artery using CT Images.

The structuring element can be represented in the form of matrix with elements either 0 or 1. The size of the structuring element is basically defined by the dimensions of the matrix, and the shape of the structuring element is determined by the pattern of zeros and ones. Fig. 1 shows for example square, triangle, diamond, cross, circular and anti-circular shaped 5×5 structuring elements.

1	1	1	1	1		0	0	0	0	1		0	0	1	0	0		0	0	1	0	0
1	1	1	1	1		0	0	0	1	1		0	1	1	1	0		0	0	1	0	0
1	1	1	1	1		0	0	1	1	1		1	1	1	1	1		1	1	1	1	1
1	1	1	1	1		0	1	1	1	1		0	1	1	1	0		0	0	1	0	0
1	1	1	1	1		1	1	1	1	1		0	0	1	0	0		0	0	1	0	0
		Square						Triangle						Diamond						Cross		

0	1	1	1	0		1	0	0	0	1
1	1	1	1	1		0	0	0	0	0
1	1	1	1	1		0	0	0	0	0
1	1	1	1	1		0	0	0	0	0
0	1	1	1	0		1	0	0	0	1
		Circular						Anti-Circular		

Fig. 1. Structuring elements of size (5×5) pixels

Structuring elements need to have an origin. Alike the convolution process, the morphological operation will produce a certain result depending on the shape and the relation between structural element and the image content. The proposed work investigates the effect of different structuring elements.

Etho and Quan [6] proposed a method based on pure morphological operators for the detection of coronary artery tree. In [7] Yang Yang used morphological operations to segment blood vessels of heart using a circular disk type structuring element.

Methodology. The developed method (in brief) consists of the following steps shown in fig. 2

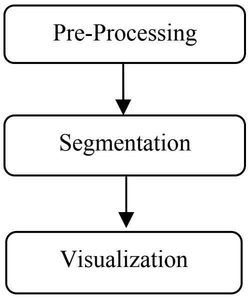


Fig. 2. Developed method.

In preprocessing step we applied several basic image processing operations and extracted the 3D heart shape. Among the basic image processing operations we applied “Thresholding” and “Dilation”. Fig. 3, *a* shows the volume rendered original image. Fig. 3, *b* shows the output image after applying “Thresholding” on fig. 3, *a*. Fig. 3, *c* shows the output image after applying “Dilation” on fig. 3, *b*. To extract 3D heart shape we used region extraction algorithm [5]. Fig-3.d shows the result after applying region extraction algorithm (using structural element of square Shape) on fig. 3, *c*. Although we have made a comparison using structural element of different shape, we are not showing the effects at this stage because the effects of different structuring element can’t be understood from the output of region extraction algorithm. Rather the difference would be clear from the final output. The comparison is shown in Experimental Results section.

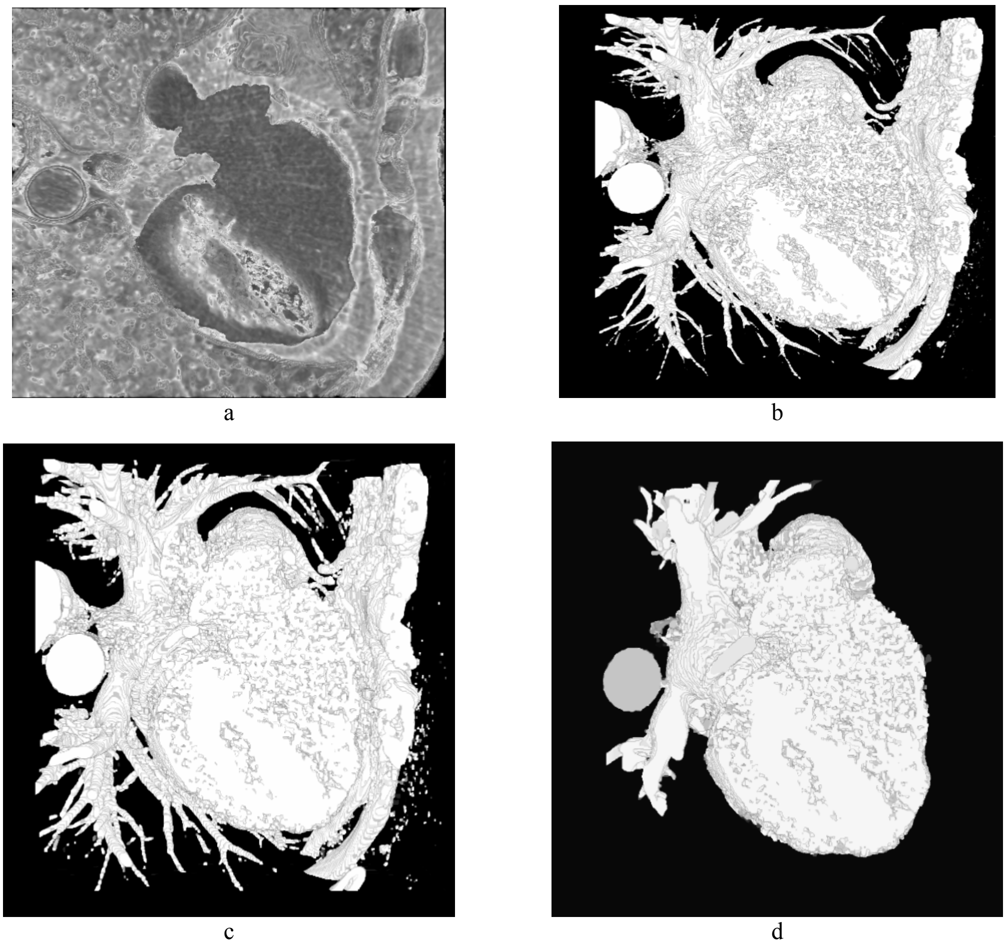


Fig. 3. Output of different steps of preprocessing

In segmentation step we have clustered the heart into three regions (as did Yan Yang, Allen R. Tannenbaum and Don P.Giddensin in [8]) (blood, myocardium and background) using Gaussian functions (eqn-1), Bayes’ theorem (eqn-2) & K-means clustering (fig. 4 shows the result) and then active contour to get the coronary artery (fig. 5 shows the result of applying active contour on fig. 4 and the effects of applying different structural element).

$$\Pr(V(x)=v \mid x \in c) = \frac{1}{\sqrt{2\pi\sigma_c}} \exp\left(-\frac{(v-\mu_c)^2}{2\sigma_c^2}\right) \quad (1)$$

$$\Pr(x \in c \mid V(x)=v) = \frac{\Pr(v(x)=v \mid x \in c)\Pr(x \in c)}{\sum_{\gamma} \Pr(V(X)=v \mid x \in \gamma)\Pr(x \in \gamma)} \quad (2)$$

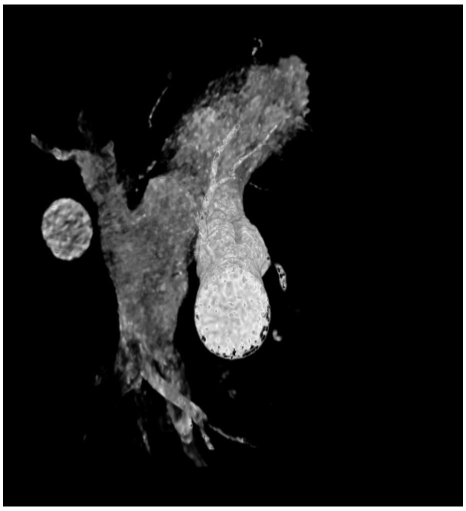
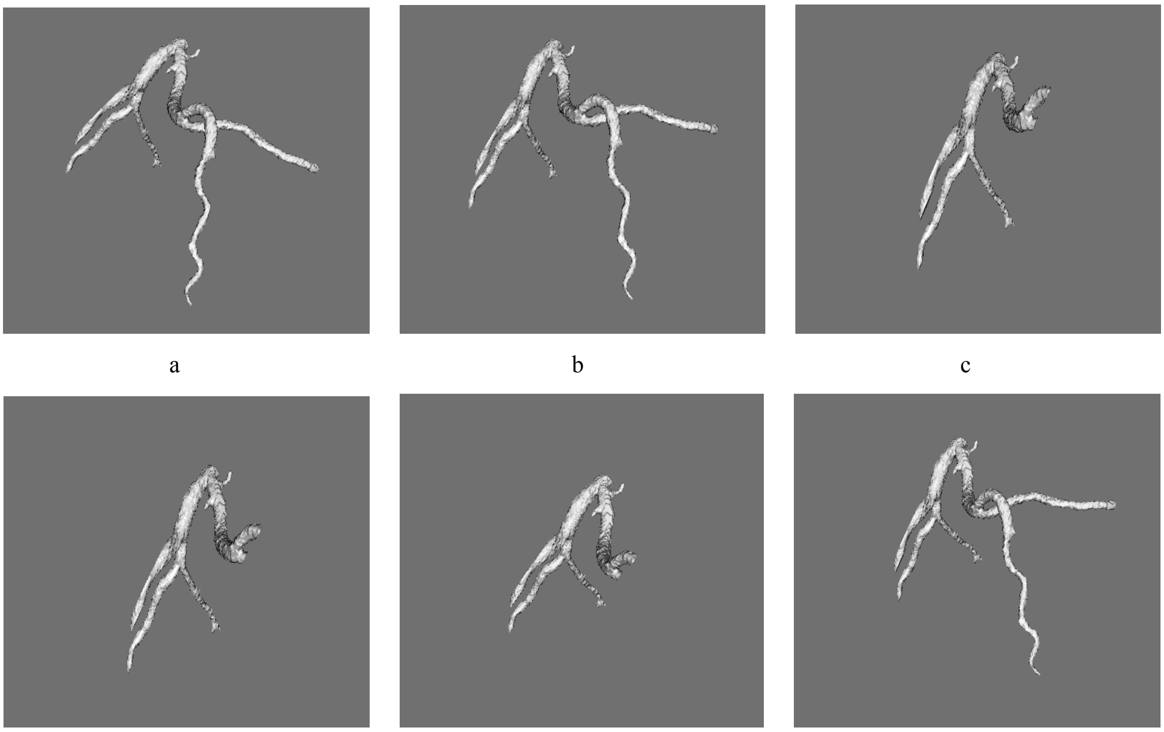


Fig. 4. Output of clustering into three regions (blood region is shown as it contains arteries)

Finally, we developed a Visualization Toolkit (VTK) pipeline to 3D visualization of the segmented branches.

Results. Runtime and the number of branch using different structural elements are given in fig. 5. (*a* – using structural element of square shape; *b* – using structural element of triangle shape; *c* – using structural element of diamond shape; *d* – using structural element of cross shape; *e* – using circular disk structural element; *f* – using anti-circular disk structural element).



a b c

d e f

Fig. 5. Effect of different structuring elements

Comparison. Comparison of Runtime of 3D heart shape extraction and number of branches of left coronary artery using structural element of size 13×13 of different shapes is given in table 1.

Table 1

Run time and segmented branches

Structural element	Runtime(ms)	No. of branches
Square	214273	5
Triangle	249043	5
Diamond	200330	4
Cross	174345	4
Circular Disk	230097	4
Anti Circular Disk	208825	5

Tested computer configuration is 1GB memory, 1.8 GHz processor and the proposed method is implemented using VTK and C++. The dataset volume is $225 \times 512 \times 512$ voxels.

Conclusion. From the above fact findings it is proved that structural elements for morphological operations play a vital role in arteries segmentation. The anatomical structural of heart is complex and robust so the improper selection of structuring element leads to insufficient branch segmentation. At the same time structuring elements have impact on segmentation time.

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РЕЗЮМЕ

Ишемические болезни сердца – одна из самых распространенных причин смертельных случаев не только в Бангладеше, но также и во всем мире. Трехмерная сегментация артерий сердца играет важную роль для анализа ишемических болезней сердца. Она также помогает врачам принимать безупречное решение для процедуры лечения и хирургии. Морфологические операторы играют важную роль при сегментации формы объекта в обработке медицинских изображения. Морфологические операторы используют структурные элементы для обработки изображения. В этой работе мы осуществили работу шести структурных элементов для сегментации изображений компьютерной томографий коронарных артерий сердца. Она показывает, что различные структурные элементы имеют существенное влияние на сегментацию артерии и продолжительность обработки.

Ключевые слова: структурированный элемент, морфологические операторы, сегментация, коронарная артерия, CT.

РЕЗЮМЕ

Коронарна хвороба серця є однією з найбільш поширених причин смертності не тільки в Бангладеші, а й у всьому світі. 3D сегментація артерій серця відіграє важливу роль для аналізу коронарної хвороби серця. Вона також допомагає лікарям приймати досконалі рішення для процедур лікування та хірургії. Морфологічні оператори відіграють важливу роль у сегментації форми об'єктів у обробці медичних зображень. Морфологічні оператори використовують структурні елементи для обробки зображень. У даній роботі ми реалізували роботу шести структурних елементів для сегментації зображень комп'ютерної томографії коронарних артерій серця. Вона показує, що різні структурні елементи мають значний вплив на сегментацію артерій і час обробки.

Ключові слова: структурований елемент, морфологічні оператори, сегментація, коронарна артерія, CT.

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