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EXTRACTION OF CORONARY VESSEL STRUCTURES IN LOW QUALITY X-RAY ANGIOGRAM IMAGES

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Abstract

We studied an automatic model based segmentation method extracting blood vessels in poor quality coronary angiograms. This method employs circular sampling method to extract blood vessels in the angiograms and exploits the spatial coherence existing in the image. Here, a 2D pattern matching method is used because 3D model based pattern matching methods are expensive and complex processes compared to the 2D techniques. The segmentation method employs the circular sampling method to produce the 2D slice samples at certain depths on each pixel on a varying background on the image. Therefore, several 2D sample slices of the 3D pattern of blood vessels are collected. Each 2D sampled slice is divided into several sub-regions and each sub-region is compared with the original pattern's sub-region. Finally, results from several overlapping 2D slices are evaluated collectively and checked whether it represents a 3D blood vessel histogram. Angle couples and circular filtering methods are employed in elimination of discontinuous parts and the incorrectly segmented noisy parts in producing the final segmented image. The result of performance tests of the method applied on various qualities of X-ray angiograms shows that the presented method achieves a quite good performance in automatic segmentation.

Index terms: Segmentation, vessel, angiogram, pattern matching, circular sampling.

1. Introduction

Several medical imaging methods such as X-ray, Computed Tomography (CT), and Magnetic Resonance (MR) are used to visualize blood vessels of human body. Extraction of blood vessels in medical images with noisy signals, drift image intensity, and low contrast pose is a significant challenge in medical image processing. Automated systems and high processing throughput are needed in computationally intensive tasks including visualization of coronary blood flow and tree-dimensional reconstruction of vascular structure from biplane medical images [1, 2, 3, 7, 8]. Previously developed algorithms for blood vessel segmentation in medical images are limited by at least one of the following drawbacks. Firstly, method may only be applicable for limited number of morphologies. Secondly, user involvement is needed to select the region of interest. Thirdly, under varying image conditions, lack of adaptive capabilities may result in poor quality of segmentation. Lastly, blood vessel segmentation process requires large computational effort. In this study, an automated blood vessel segmentation method is developed to extract blood vessels on images with a broad range of quality [5, 6, 9, 11].

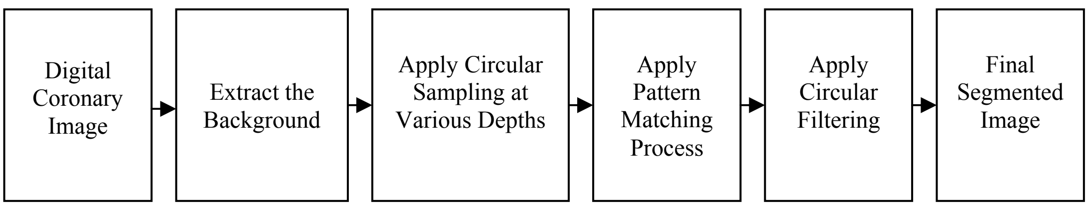

Figure 1. A block diagram of the segmentation process of the proposed system

The rest of this paper is organized as follows. After the introduction in section 1 an overview about the implementation details of the developed system is given in section 2. The implementation and results are discussed in section 3. The conclusions and future work are also given in the same section.

2. Description of segmentation method

The spatial coherence existing in the medical image between current and neighboring pixels is utilized in segmentation. This coherence is exploited in tolerating the effect of local discontinuities and disorder, thereby improved the success in recognition of normal and distorted blood vessel in a noisy image in automatic segmentation. Here, heights and lowness in medical images are considered as if they are part of a geographical objects rather than a gray scale image. In these objects, the heights, generally high intensity areas, may be considered as blood vessels and locally lower areas, usually low intensity areas unlike heights, are non-blood vessel parts such as other tissues, bones, and etc. A block diagram of the segmentation method is given in Figure 1. The basic operations in automatic coronary segmentation method are (1) filtering, background extraction and classification of the images at sampling points, (2) circular sampling at varying depths (3) 2D pattern matching; adaptive rotation, scaling, changing patterns and calculation of slope from the matching 2D patterns for 3D pattern matching, and (4) circular filtering.

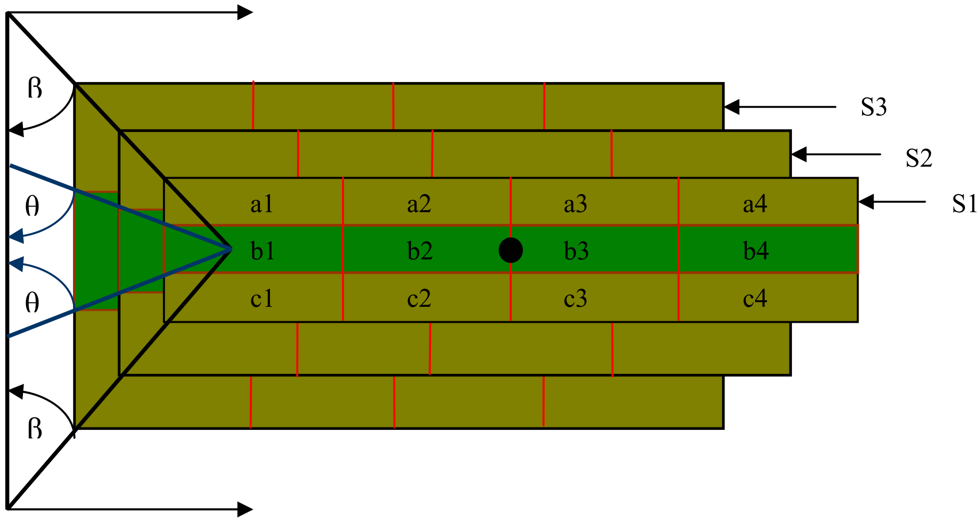

Figure 2. Several 2D samples forms a 3D blood vessel

The segmentation process of the blood vessel in a medical image is negatively affected by the background of the image. Thus, the circular sampling method will sample the object incorrectly, if the background effect is not eliminated properly. Therefore, a method is needed to prevent the background effects. As seen in Figure 2, after the circular sampling process, several 2D patterns at a certain depths are generated. A typical pattern consists of blood vessel in the middle and spaces in two sides. The simple 2D pattern matching technique is applied to segment the blood vessels on a medical image. Each of 2D sample slices is divided in to sub regions according to the matching patterns depicted in the figure. These sub regions are compared with the corresponding sub regions of original patterns. Then, the similarity test is applied to measure the similarity between sub pieces of sample and original patterns collectively. All of the sub pieces of a sample and original patterns are illustrated in the figure as *a1 to a4, b1 to b4, and c1 to c4.* In this similarity test, for bending blood vessels, the multiplications of results such as a1*c1 and a4*c4 are also calculated to strengthen the accuracy of the segmentation. If several sample slices pass the first similarity test, then slope test is applied to all 2D samples as depicted in the figure. In other words, all 2D slices are checked collectively to find out whether they construct the 3D blood vessel structure. The angle θ, illustrated in the figure, is checked to see whether it is bigger than a threshold value. If the angle, for example 70 degree, is bigger than a threshold value, 3D structure is most probably to be a histogram of a blood vessel. Then, the pixels or pixels around the current point are segmented as blood vessel or space according to pre-classification results of the current pixels. Generally, vessels in a medical image are continuous and long structures. On the other hand, sometimes background and noisy structures could be detected as vessel structures but they actually are more often discontinuous and short vessel like structures rather than long and continuous vessel structures. These incorrectly segmented parts can be removed from the final image by using circular filtering method [4, 10].

3. Results and Conclusions

In this paper, an automatic segmentation method is presented to extract blood vessel structures in poor quality coronary angiograms without human intervention. This method utilizes the circular sampling and pattern matching methods to exploit the spatial coherence in an image. An adaptive 2D pattern matching method with limited original pattern stack is employed to segment blood vessels in a medical image. Although, proposed method with the small pattern stack produces quite satisfactory segmentation results, the number of patterns on the original pattern stack can be increased for further increase in success of segmentation. A background elimination method is also employed to minimize the effects of chancing backgrounds on segmentation process. At final step of the segmentation process, a circular filtering method is used to improve the quality of the final image.

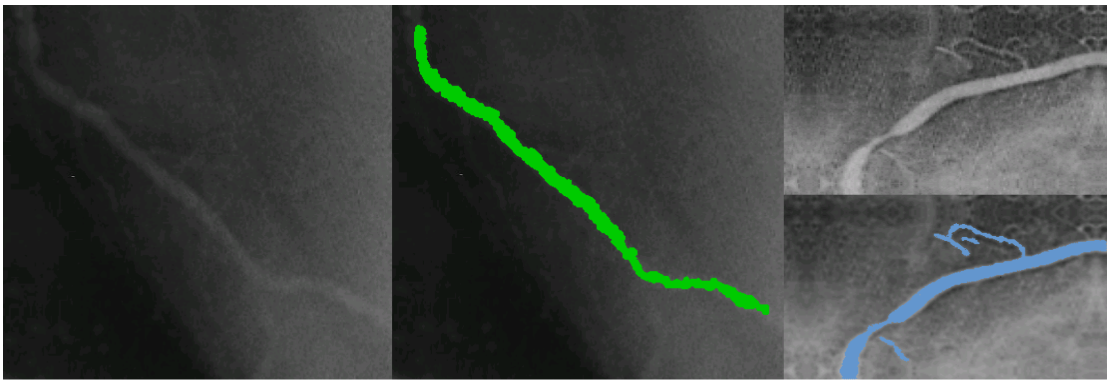

Figure 3. A low intensity and a real image with noises

In the application, some real medical images are used to measure the performance of segmentation method. Here, images are obtained from a CT or MR scanners. These real images reflect some properties that make the segmentation more difficult as shown in Figure 3. Proposed segmentation method is tested on these real medical images that are poor in quality, have low intensity and noisy parts. The performance of the method is also measured on these medical images with noisy branches, changing background and intensities. One of the images with sharp background changes and its segmentation results is presented in Figure 4. Blood vessels on these images are quite successfully tracked and segmented without user intervention. The segmentation time for the image given in the Figure 3 is about 32 seconds. Typical length of time period for the segmentation of an image with dimension of 600x700 pixels given in Figure 5 is about 145 seconds.

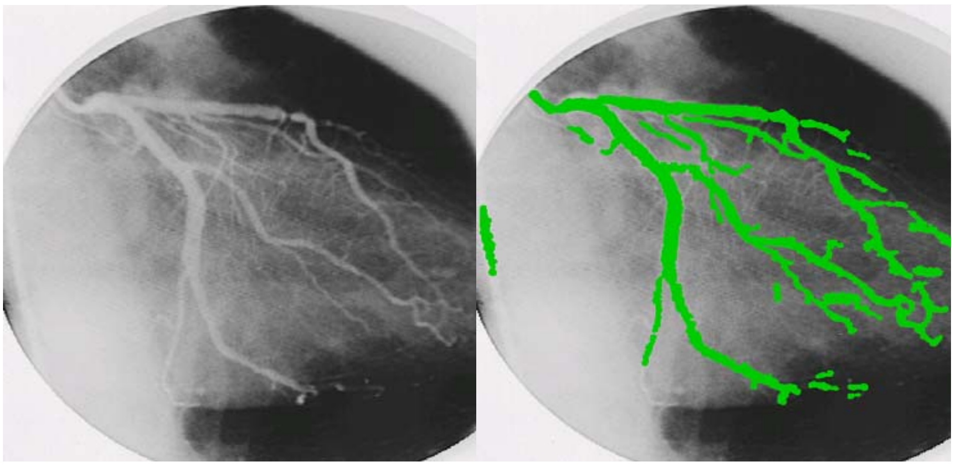

Figure 4. One medical image and its segmentation results

Proposed segmentation method with very limited pattern stack quite successfully segments the poor quality medical images. Also, a large range of medical images are successfully segmented by using the recognition method. Here, an adaptive pattern rotation and pattern scaling methods are also employed to reduce the segmentation time. A Monte Carlo method could also be applied to reduce processing time per 2D slice while rotating, scaling and comparing the patterns.

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