Coronary Arteries Segmented Using SIMULINK Model in MATLAB

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Abstract

In this paper, a simulation for segmentation of coronary arteries of heart has been developed on 2-D CT (Computed Tomography) isolated data in MATLAB 2009a using Simulink Library. 64- Slice CT Scan technology provides a noninvasive method to directly visualize the coronary arteries. Using a small dose of contrast, 64-slice CT angiography provides previously unobtainable visualization of the Coronary arteries. A simulink model has been developed using different image processing block sets from MATLAB. MATLAB Simulink Library provides a variety of opportunities and methods to process images through the different image processing blocks to obtain the desired image with the required feature or objects of the images extracted or segmented. The basic data structure in MATLAB is the array, an ordered set of real or complex elements. This object is naturally suited to the representation of images, real-valued ordered sets of color or intensity data. MATLAB stores most images as two-dimensional arrays (i.e., matrices), in which each element of the matrix corresponds to a single pixel in the displayed image. Pixel is derived from picture element and usually denotes a single dot on a computer display. We have developed a MATLAB Simulink model for visualization of main coronary arteries of heart. We have used Computed Tomography (CT) scan image of heart. In developing the Simulink model, we used the Video and Image Processing Blockset software tool in MATLAB. The Video and Image Processing Blockset software is a tool for processing images and video in the Simulink environment. The Video and Image Processing Blockset software is a tool used for the rapid design, prototyping, graphical simulation, and efficient code generation of video processing algorithms. Video and Image Processing Blockset blocks can process images or video data. These blocks can import streaming video into the Simulink environment and perform two-dimensional filtering, geometric and frequency transforms, block processing, motion estimation, edge detection and other signal processing algorithms. You can also use the blockset in conjunction with Real-Time Workshop to automatically generate embeddable C code for real-time execution. Video and Image Processing Blockset blocks support floating-point, integer, and fixed-point data types. The different image processing blocks used in developing the Simulink model for the segmentation of main coronary arteries in heart CT scan images are Analysis and Enhancement blocks, Conversions, Filtering, Morphological and Geometric Transformations blocks. This system would be effective in assisting the physician to visualize coronary arteries of heart.

Keywords - MATLAB, Segmentation, Morphological operation, Median Filter, CAD (Coronary artery disease), Simulink.

Introduction

Many elderly people suffer from coronary artery disease. For this reason, early detection of coronary artery disease (CAD) is one of the most important medical research areas. Calcified lesions in the coronary arteries are the main indicators of CAD. Clinically significant calcified lesions are considered to be those found within the five main coronary arteries, the Left Main (LM), Left Anterior Descending (LAD), Left Circumflex (LCX), Posterior Descending (PDA) and the Right Coronary artery (RCA). The most reliable way to diagnose coronary artery disease is with an invasive procedure, cardiac catheterization. But the catheterization is costly, time consuming, and has risks. Image processing modes based on radiographic views may not completely provide diagnostic information at an early stage, when it would be easier to control a disease, make a therapeutic decision, or perform surgery. This lack of timely information requires some further processing of images to detect tumors, lesions and blockage. Coronary computed tomography angiography (CTA) provides clinically complementary information in the diagnosis of coronary artery disease (Goyal *et al.*, 2012).The standard of reference for diagnosis of CAD is still invasive coronary angiography, with the advantage of high spatial resolution and temporal resolution. Despite its cost, inconvenience to patients, and a small but distinct procedure-related morbidity (1.5%) and mortality (0.2%) rate, more than 1 million invasive diagnostic coronary angiography procedures are performed annually in the United States alone. Similarly, CAD is the single most important cause of death in India, Australia, New Zealand and other countries. Every year, billions of dollars have been spent in the treatment of coronary artery disease. Given the invasiveness of coronary angiography and potential danger of having a small risk of serious complications (arrhythmia, stroke, coronary-artery dissection and death), a non-invasive technique for imaging of the coronary artery disease is highly desirable. Imaging of the heart and coronary artery branches has always been technically challenging due to the heart's continuous movement. Over the last decade, great strides have been made in the field of cardiac imaging as non-invasive coronary imaging modalities have undergone rapid developments (Nieman *et al.*, 2001; O'Malley *et al.*, 2001; Danias *et al.*, 2004; Finn *et al.*, 2006). Coronary computed tomography angiography (CTA) is a heart imaging test that helps determine if deposits of fat or calcium (plaque) have narrowed a patient's coronary arteries. Coronary CTA is a special type of x-ray examination. Patients undergoing a coronary CTA scan receive an iodine-containing contrast material (dye) as an intravenous (IV) injection to ensure the best possible images. and allow reproducible and accurate non-invasive evaluation of coronary atherosclerotic diseases. CT scans of internal organs, bones, soft tissue and blood vessels provide greater clarity and reveal more details than regular X-Ray exams (webpage: http://www.radiologyinfo.org/en/info.cfm?pg=angiocoroct.). The coronary CT angiography studies are very promising and exciting. Non-invasive imaging of the heart and the coronaries using computed tomography (CT) or magnetic resonance imaging (MRI) has become widely accepted. The continuous motion of the heart, the small caliber and the tortuous nature of the coronary vessels make these examinations challenging. Since 1993 coronary MR angiography has been performed with temporal resolution of 40-100 ms (Duerinckx, 2002). Older generations of CT scanners have had an inadequate temporal resolution for coronary angiography. Because the 64-slice CT scanner offers faster gantry rotation, as low as 330 ms, and smaller detector arrays, it allows higher temporal and spatial resolution. The 64-slice CT scanner can visualize the entire heart in less than 10 seconds, revealing blockages in blood vessels and other heart problems that are sometimes not easily detectable with other tests (Duerinckx, 2002; De Feyter and Krestin, 2005; Oudkerk, 2004; Schoenhagen, 2004; Vanovermeire and Duerinckx, 2006, Schoenhagen *et al.*, 2005). Image segmentation facilitates delineation of anatomical structures and other regions of interest. Segmentation is one of the most difficult tasks in image processing and determines the outcome of analysis and evaluation of pathological regions. The aim of the proposed Simulink model is to segment Coronary Arteries in Heart through use of proper video and image processing blocksets. The rest of the paper is organized as follows: Simulink Model is presented in Section II. System architecture is discussed in Section III. Experimental results are presented in Section IV and analyzed. Conclusion and future work is briefed in Section V.

SIMULINK Model

The Simulink model for the system is shown in Fig. 1. It uses different simulink blocks and also video and image processing blocksets, Main blocks used in the Simulink model are shown in Fig. 1. The different steps in simulation of Coronary Artery Segmentation System of Heart are shown. These are Input CT image of Heart, sharpening the image through the color space conversion of image. After sharpening the image, we apply contrast adjustment, thresholding, filtering, edge detection and morphological operations and Displaying blocks.

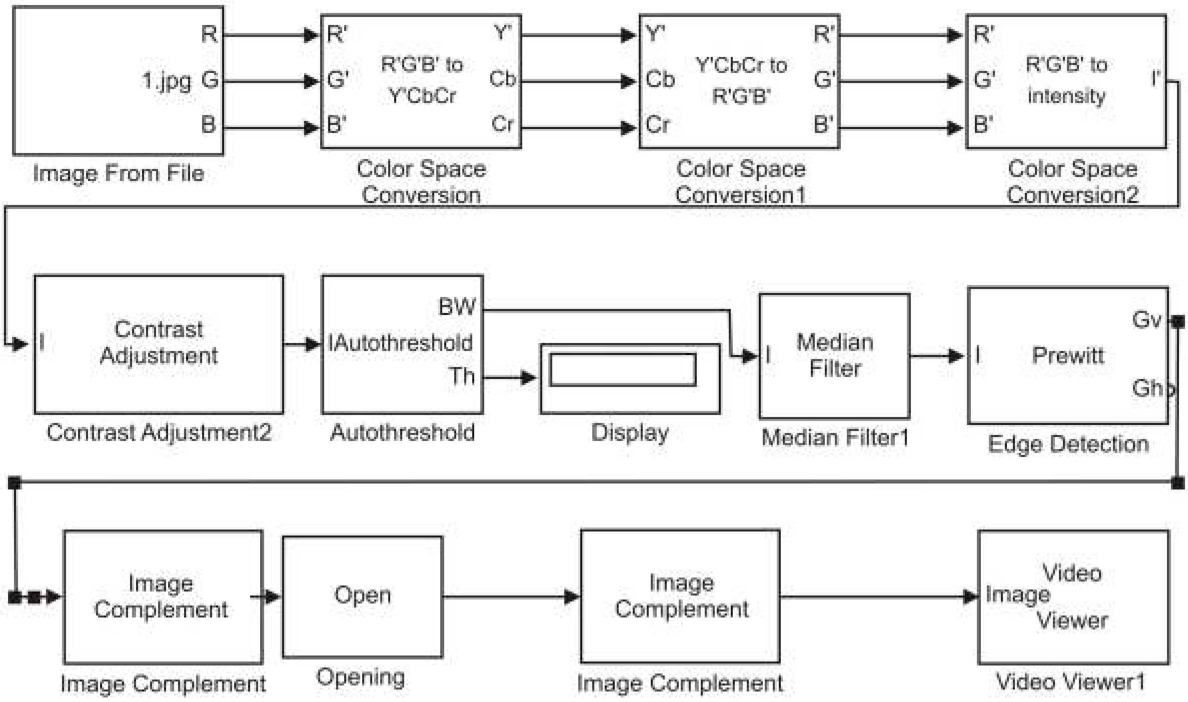

Figure1: Simulink model of coronary artery segmentation system.

System Architectutre

The flow chart of the system for the segmentation of coronary arteries of heart using 64- Slice CT Scan image is shown in Fig. 2.The proposed system uses image processing techniques and work is done in the Simulink. The main components of coronary arteries segmentation system are 2-Dimensional FIR (Finite Impulse Response) filter, thresholding based segmentation of heart image, edge detection technique and morphological operations.

Selecting a Heart CT Scan Image

The very first step to segment the coronary arteries of the Heart is to choose the suitable 64-Slice CT Scan image. The selection of a suitable image is done in such a way that it contains almost all the coronary arteries of the Heart.

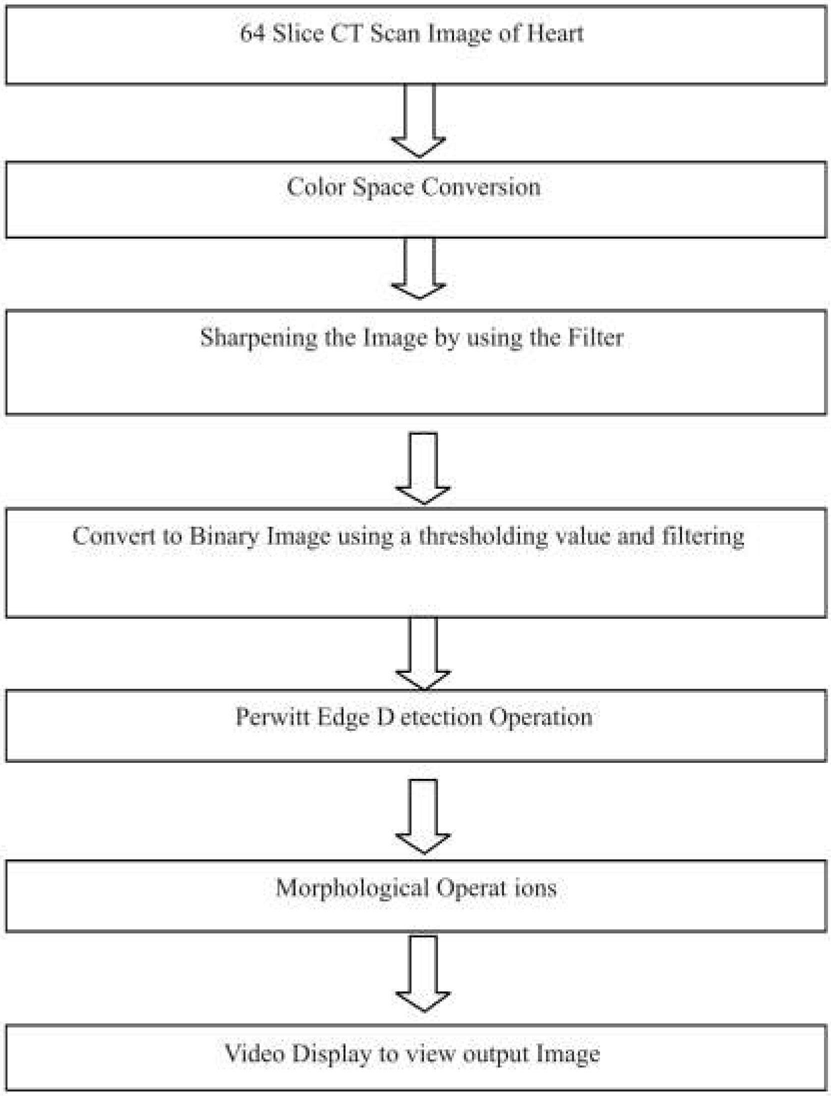

Figure 2: Coronary arteries segmentation system flowchart.

For this to happen, we must choose such a direction of the imaging in the Computed Tomography that the acquired image contains most of the arteries of the Heart and we can process this image to get its desirable parameters to diagnose the diseases of heart.

Sharpening of Image

CT images are found to have random noise. The random distortion present in the image makes it difficult to perform perfect image processing. So, it is necessary to remove the random noise from the image. To sharpen a color image, you need to make the luma intensity transitions more acute, while preserving the color information of the image. To do this, you convert an R'G'B' image into the Y'CbCr color space and apply a highpass filter to the luma portion of the image only. The YCbCr color space is widely used for digital video. In this format, luminance information is stored as a single component (Y), and chrominance information is stored as two color-difference components (Cb and Cr) (MATLAB 2009a Simulnk library help/ Color image processing Toolbox/ Converting Color data between color spaces).

Cb represents the difference between the blue component and a reference value. Cr represents the difference between the red component and a reference value. YCbCr data can be double precision, but the color space is particularly well suited to uint8 data (MATLAB 2009a Simulnk library help/ Color image processing Toolbox/ Converting Color data between color spaces). Then, you transform the image back to the R'G'B' color space to view the results. Fig. 3(a) and Fig. 3(b) show the Binary Image before sharpening and Binary Image after sharpening through the color space conversion and applying the Finite Impulse Response Filter respectively (MATLAB 2009a help/ Video and Image Processing Blockset/Product Overview). Finite impulse response (FIR) filter is a filter whose impulse response (or response to any finite length input) is of finite duration, because it settles to zero in finite time. FIR filters have advantages like exactly linear phase, always stable, linearly designable and FIR filter startup transients have finite duration (MATLAB 2009a help/ Video and Image Processing Blockset/Product Overview).

Figure 3 (a): Binary image before sharpening. **Figure 3 (b):** Binary Image after sharpening.

Image segmentation and pre-processing

After the Image sharpening, the image was segmented using a threshold value of 0.0784. The thresholding provides the binary image. The binary image data type was converted to make it suitable for edge detection. Before the edge detection, we applied the median filter. The Median Filter block replaces the central value of an M-by-N neighborhood with its median value. If the neighborhood has a center element, the block places the median value there (MATLAB 2009a Simulnk library help/ median filter/Overview). The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing. Under certain conditions, it preserves edges while removing noise(http://en.wikipedia.org/wiki/Median_filter). After the filtering again with the Median filter, the Perwitt edge detection operator was applied, that output the horizontal and vertical gradient components of the image separately.

Morphological operations

Morphology is the study of the shape and form of objects. Morphological image analysis can be used to perform object extraction, Image filtering operations, such as removal of small objects or noise from an image, Image segmentation operations, such as separating connected objects, Measurement operations, such as texture analysis and shape description. The Video and Image Processing Blockset software contains blocks that perform morphological operations such as erosion, dilation, opening, and closing. Often, you need to use a combination of these blocks to perform your morphological image analysis. Morphological image analysis can be used to perform image filtering, image segmentation, and measurement operations. (MATLAB 2009a Simulink Library help/image processing Toolbox/Image enhancement/sharpening and blurring of image). After the Perwitt edge detection operator applied, different morphological operations like opening, closing, dilation etc. were applied gradient component of image because it provides better segmentation of coronary arteries in heart. After applying the morphological operations, contrast adjustment was applied and finally we got the image showing the segmented coronary arteries as output shown by video viewer.

Inference

When 64- Slice Computed Tomography 2-D image of Heart is given to the Simulink model developed, the image is sharpened, thresholding is applied, filtering and morphological operations are applied on the image and finally image with segmented coronary arteries of heart is obtained. The segmented coronary arteries can be processed in MATLAB Simulink to diagnose the diseases at early stage through determination of different characteristics of coronary arteries like eccentricity, Bounding Box, Diameter, Solidity, Aspect Ratio, etc.

Simulation Results

The system was tested on different 2-D CT images of heart and every time system performed well to extract the coronary arteries. Fig. 4(a) shows the original input image to the developed Simulink Model, and Fig. 4(b) shows the output image with segmented coronary arteries of the Heart.

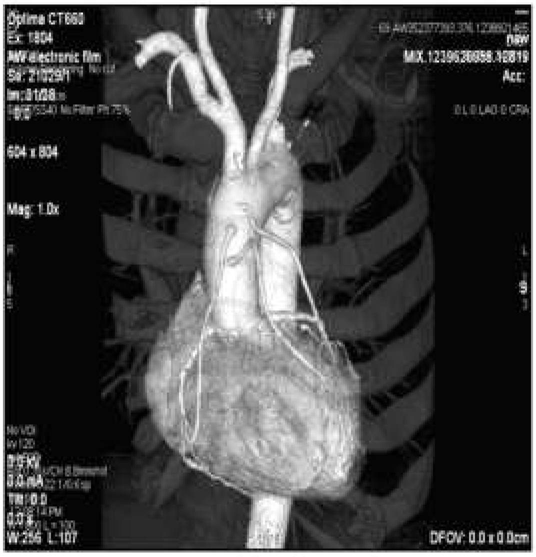

Figure 4 (a): Original input image.

Figure 4 (b): Output image with main coronary arteries segmented.

Conclusion and Future Work

The developed Simulink model is reliable and can perform segmentation of coronary arteries from the CT scan images of the Heart. This system shall be helpful to the surgeons or physicians to directly visualize segmented coronary arteries of heart.

This Simulink model can be further modified so as to be able to do more useful processing of the input image to plot the diameter of artery region from the image obtained after segmenting coronary arteries. After plotting the arteries diameter plot, a rough demarcation of the Calcification region in the arteries can be made at the places where the diameter of arteries suddenly/abruptly decreases by a large value. This Simulink model is useful to detect the Calcification in the areas where amount of Calcification is larger.

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