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Stenosis Detection Using Deep Learning

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Abstract: *Stenosis is the type of cardiovascular disease which accounts for large proportion of death. Computed Tomography Angiogram (CTA) modality is used for detection of cardiovascular diseases. CTA produces multiple images and diagnosis of stenosis in large images is time consuming. Hence, we propose an automated system to segment and track the coronary arteries in order to locate abnormalities present in the arteries. To segment the coronary arteries the vesselness has to be enhanced using hessian based approach followed by morphological operators.In tracking, the vessel direction is obtained by modelling the tensors and branches are identified using the masking method. The presence of stenosis is detected while tracking based on intensity measurement and radius variation. The execution of the proposed system has been analyzed by distinguishing the end result with the grounded images given by the professionals. Keywords: Stenosis, Deep Learning, CTA, Hessian, Morphological operators, Tensors.*

Index Terms - ***Stenosis, Deep Learning, CTA, Hessian, Morphological operators, Tensors.***

I. Introduction

Medical imaging is the technique and process of creating visual representations of the interior of a body for clinical analysis and medical intervention. Images obtained from Medical Imaging can be used in the field of Computer Science for early diagnosis and treatment of diseases. Various imaging modes for recognizing diseases are Computerized Tomography (CT), Magnetic Resonance Imaging (MRI) and Nuclear Medicine. The images obtained from these techniques will be of DICOM or TIFF format. Cardiovascular disease (CVD) is a disease that involves the heart or blood vessels. Common CVDs are: Congenital Heart Disease (CHD), ischemic heart disease (IHD), stroke and peripheral artery disease (PAD). These mechanisms vary depending on the disease. IHD, stroke, and PAD involve atherosclerosis. Atherosclerosis has a particular form in which an artery wall thickens as a result of invasion and accumulation of white blood cells. These accumulations contain both living, active white blood cells and remnants of dead cells. The remnants at last includes calcium and other crystallized materials, within the outermost and oldest plaque. These will narrow the arteries and hence reduce the blood flow which will cause heart attack. This narrowing of blood vessels is called stenosis and may occur in any part in the body. Coronary artery is the one that is extensively involved stenosis. It is covetable to design skilled screening procedures for the initial diagnosis and fitting treatment of cardiovascular diseases.We propose an idea to detect stenosis in the coronary arteries.

II. LITERATURE SURVEY

[1] is tested with the idea of developing a vessel enhancement filter. The vesselness is obtained based on the Eigen values of hessian matrix. The main purpose of [1]is to suppress the noise and background in the images while enhancing the vessel with maximum intensity. The main hindrance is maximum intensity projections are the overlay of non-vascular structures and the small vessels with low contrast are rarely visible.

[2] proposes an automated determination for centre line tracking. The vessels are detected automatically using modified sector search approach. The perimeters of sectors centered on previous tracking points are searched for the pixels with the supreme contrast. The sector size and radius are mechanically adjusted based on local vessel complexity. This proficiency can provide a trustworthy basis for 2D and 3D vascular analysis. The disadvantage of this tracking is that the result will be incorrect for low signal-to-noise ratio.

A heart surface vessel segmentation and 3D reconstruction mechanism is described in [3]. De-correlation stretch algorithm is utilized for image enhancement process of the vessel ROI where the operation is to be performed. The segmentation process correctly detects the vessels even if fats cover the surface of the heart although it can be affected by the lighting conditions in the color images.

Multi-scale Hessian Matrix approach [4] is a three dimensional efficient automatic method for lung vessel segmentation. The advantage of this algorithm is that it can be used in multiple scans and has better performance with thinner slices. Hessian based approach provides a maximum value at a given scale that should match the size of the vessel and is chosen to be the intensity value. This approach finds the tubular structures in an image. The disadvantage of [4) is that maximum scale value has to be fixed in order to prevent huge computational costs of the different scaled matrices.
[5] presents a 3D image processing method that is based on the analysis of Hessian matrix combined with a multi-scale image analysis approach. The advantage of [5]is that it can operate in 2D or 3D images. However, this method was developed mainly for detecting blood vessels and cannot be directly used for airway tree detection and enhancement. Although Airway tree detection cannot be utilized in [5], it still considers the possibility to adapt for different intensity cross section profile.

[6]utilizes the concept of level sets to remove noise in the image, to enhance the image, and to track the edges of the vessels. In order to enhance and remove noise in the images, a level set method is used. For tracking an interface is implemented which propagates through the blood vessels. The level set and fast marching methods have been researched broadly for use on medical images from brain MRIS to arteriogram. The limitation of this approach is that it is not fully independent for some images.

[7]proposes a tubular structure segmentation method that uses a second order tensor constructed from directional intensity measurements. For tracking Intensity based tensor model is used. In this method tensor matrix is formed from which Eigen values and vectors are found to get the direction of the vessel. Vessel tractography model is extended to tubular trees by developing K-means clustering method to track along the branches. For noisy data sets the number of tensors to be considered should be greater than seven for obtaining good results. The main drawback presented in [7] is that tracking does not occur along the centre line of the vessel. To improve this situation centralization scheme is applied.

III. EXISTING SYSTEM

The system is examined with the purpose of developing a vessel enhancement filter. The vesselness is obtained based on the Eigen values of hessian matrix.The main purpose of this system is to suppress the noise and background in the images while enhancing the vessel with maximum intensity.The main drawback of maximum intensity projections are the overlap of non-vascular structures and the small vessels with low contrast are hardly visible.

IV. PROPOSED SYSTEM

The input CTA images are obtained from medical experts which is in the form DICOM format(Digital Imaging and Communications in Medicine) and are converted to TIFF image by a special software called OSIRIX such that no data is lost.The input tiff image is resized and then converted to gray scale image. Inorder to improve the vesselness, multi scale Hessian based approach have been used for image enhancement. Gaussian function is used to define gaussian blur in image processing.i.e. it reduces the noise in the images.Traversing through blood vessels in coronary artery through the centerline is done using vessel tractography method and the seed(initial) point is found using contour function. Then the direction of the consecutive points can be found using intensity based tensor method.To construct a tensor, create a circle enclosed in a rectangle. With the seed point as center, draw a circle of best fit radius.Stenosis is the sudden narrowing of blood vessels. We can detect the narrowing of blood vessels by comparing the radius of the current and the previous points while tracking. When there is an abnormal change in the radius, stenosis is detected.

V. ARCHITECTURE

The system consists of Three Modules, Segmentation, Tracking and Detection of stenosis. In segmentation the vessels are completely segmented from the input image after applying morphological operator, tophat followed by thresholding. In Tracking the segmented vessels are tracked by constructing tensors. In Detection of Stenosis the presence of stenosis is detected using intensity and radius measurements

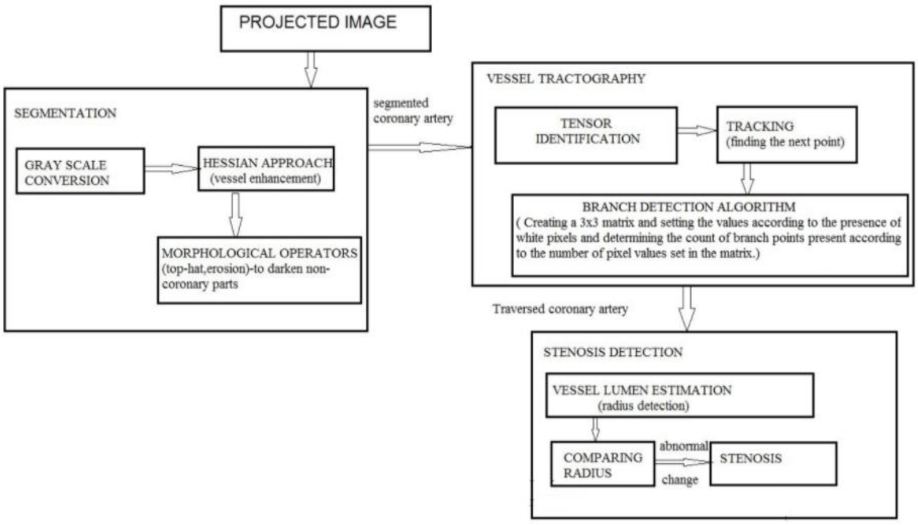


FIGURE 1. ARCHITECTURE DIAGRAM

VI. IMPLEMENTATION

The input to the preprocessing module is 2D heart CTA image in DICOM format. Since it is difficult to process these images, they are converted to 2D projection images. The DICOM images are first converted into TIFF format using OSIRIX software. The obtained TIFF images are resized as per the requirements. The following steps are carried out to segment the blood vessels from the heart image.

Gray scale conversion, where Input is a RGB Color Image. It converts input image from one color space to another. Inorder to improve the vesselness, multi scale Hessian based approach have been used for image enhancement. The main purpose of using Hessian matrix is to suppress the noise in the image background while enhancing the vessel with maximum intensity. Morphological operator, top hat followed by thresholding is applied to the input image. Repeated thresholding is applied inorder to remove blobs from the image. The output image has the segmented vessels.

For tracking, Skeletonisation is applied to the input image to get the centerline of the vessels.. A morphological skeleton can be computed using the two basic morphological operations: dilate and erode. The skeleton can be produced by morphological thinning that successively erodes away pixels from the boundary until no more thinning is possible.For finding contour, the input is the skeletonised image. The first and the last points are found for the given contour. This first point is assumed to be the initial seed point for tracking the coronary arteries.To track the blood vessels, tensors are used to find the direction of blood vessel. To construct a tensor, a circle is created that is enclosed in a rectangle. With the seed point as center a circle is drawn with the best fit radius. To determine the best fit radius, 2-NORM ($dt * d$) of tensor matrix is found.From the resultant matrix of $dt * d$, maximum eigen value (λmax) is found.The square root of λmax is found.This procedure is carried out for different radius values (rmin to rmax).The radius value for which λmax is maximum is set as the radius of the circle for the considered point.

Branch Detection Algorithm method detects the presence of branches and its count. By thinning algorithm, segmented blood vessels are reduced to unit width pixel. A 3x3 matrix is created at a current coordinate where the current coordinate is the center of the matrix. The matrix values are checked for the presence of white pixels.If there exists white pixels then the count is incremented. If the count is three, this means that tracking is done along the centerline of the vessel. If the count is four or more, then branches are indicated.These values are stored for tracking purposes. If the count is two, then this is an end point. The stored branch points are then given as the seed points for vessel tractography.

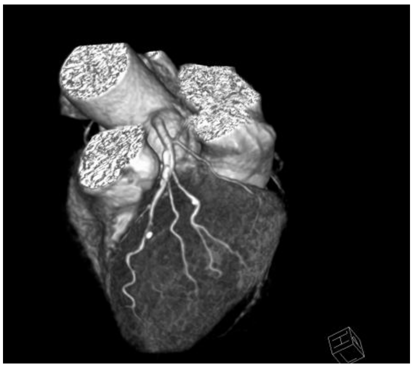
STENOSIS DETECTION:

For stenosis detection, there exists two different cases.

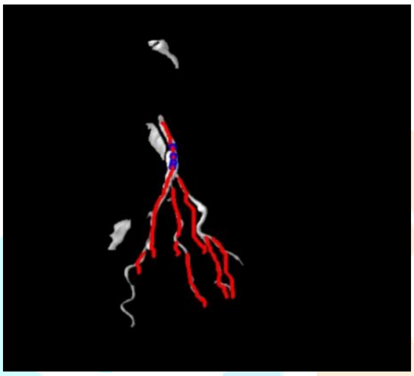
CASE 1:The radius of the current coordinate is compared with the previous coordinate while tracking. If there is an abnormal change in the radius, then there exists stenosis.

CASE 2:CASE 1 along with the higher intensity variation of the current coordinate should be satisfied to ensure presence of stenosis.

INPUT IMAGE:



OUTPUT IMAGE:



VII. CONCLUSION

An automated system has been successfully designed to segment and track the coronary arteries for stenosis detection.For segmentation, vessel enhancement is achieved by hessian based approach and non coronary arteries are removed by morphological operators.Then tracking is done by modelling the tensors to move along the vessel direction. Finally stenosis is identified.

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