Identification and Visualization of Vulnerable Atherosclerotic Plaque for Predicting Risk Factors of Heart Attack

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Abstract— The challenging image method is to view patient with high-risk vulnerable plaque. To identify intraplaque haemorrhage, vasa vasorum and luminal thrombi rupture. Many non-stenotic lesions undergo "expansion", and it leads to myocardial infarction (heart attack). Hence, we investigate the proposed technique for coronary atherosclerosis to develop an effective image segmentation method such as extraction of aterial lumen in centreline, segmentation of the lumen & wall. Using CT angiographic image Morphological operators such as dilation and erosion takes out the unwanted background. The physical properties such as the fluid flow rate, coronary wall shear stress, thickness, type of plaque identified using COMSOL/MATLAB. Finally, results assist the risk factors of a heart attack at various stages.

Keywords: Vulnerable Plaque, Myocardial Infarction, Morphological Operators, Type of Plaque

I. INTRODUCTION

Atherosclerosis is a vascular inflammation disease, which is the primary cause of myocardial infarction (MI), ischemic gangrene and stroke. Atherosclerosis is a progressive disease, which begins at the stage of childhood and results in thrombus formation on the surface of a plaque. It includes disorders such as family history, hypercholesterolemia, hypertension, smoking, obesity, and indicates immune responses. Attention directs at the evaluation of plaque characteristics and biological processes that investigate the dangerous level. Various methods, includes ultrasound, multi-slice Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Single Photon Emission Computed Tomography (SPECT), Intravascular Ultrasound (IVUS), Optical Coherence

Tomography (OCT), and others to evaluate the presence of vulnerable atherosclerotic plaques. However, many of these modalities are invasive or yield a low spatial resolution. Non-invasive Positron Emission Tomography (PET) imaging of inflammation in plaque offer a useful tool to predict the risk of plaque rupture and allows monitoring of anti-atherosclerotic drugs. Atherosclerosis results in prevention of acute cardiovascular events. Early atherosclerotic lesions, known as an initial lesion or fatty streak, consist of subendothelial accumulations of cholesterol-filled macrophages (foam cells). In humans, such injuries are present in the aorta in the first decade, damage coronary arteries in the second decade and the cerebral arteries in the third or fourth decades of life.

Due to some differences in blood flow dynamics, the curvatures and bifurcations of arteries are capable to increase the permeability of cholesterol-rich macromolecules. Such macromolecules include low-density lipoprotein (LDL) used for lesion formation. The first events surrounding lipid accumulation is unclear. Elevated levels of inflammation, plasma cholesterol, endothelial dysfunction play a significant role in disease progression. After LDL accumulates in the intima, it undergoes some changes like oxidation, aggregation, lipolysis, proteolysis.

Plaques in arteries may cause flow-limited stenosis, which can lead to clinical complications. However, for blood circulation, the most severe clinical events commonly caused by the rupture of a plaque, expose the pro-thrombotic material. At the site of artery, plaque leads to generate sudden thrombotic occlusion. This rupture-prone plaque commonly called as vulnerable plaque. Typically, such a vulnerable plaque may not cause dangerous stenosis, but it comprises a large lipid core and a thin fibrous cap that often infiltrates by inflammatory cells, particularly at the plaque's shoulder areas. Thrombotic occlusion of a single atherosclerotic plaque causes many deaths. A simultaneous occurrence of a pair of occlusive thrombi is rare, but a second vulnerable plaque is typical. The thickness of the intimal layer activates the endothelium to express leukocyte adhesion molecules, and chemokines encourages the recruitment of T cells and monocytes leading to a higher degree of immunological activity.

Some of the significant risks of heart attack are High Blood Pressure, High Blood Cholesterol, Diabetes, Obesity and Overweight, Smoking, Physical Inactivity, Gender, Heredity, age etc. In this work, the morphological operators such as dilation & erosion with threshold value 75 to 90 help to find the cardiac stenosis. The physical properties of the blood vessel identified using COMSOL/MATLAB for stress analysis. Type of fat, plaque thrombus analysed from the imaging data.

A. Related Works

At an early stage, atherosclerotic plaque formation integrates several steps leading to fat accumulation. The levels of cells consider low-density lipoproteins and agents. The process connects to the thickening of arteries. The vital factors for the formation of atherosclerotic plaque select mean level of blood. The location of plaque depends upon plaque size, WSS, number and the growth level is dependent on mean blood level. According to [17], plaques grow mainly in the region of arteries and considered as fatty deposits. A proposed model predicts the necrotic core development. This model anticipates the correct shape and size of the plaque core but does not imitate the mechanical properties. Plaques possess complex structures, and their composition predicted using simple models.

Based on the approach of the multi-level model [18], the significant mechanisms of plaque's growth demonstrate numerical proof models. The multi-level approach possesses three levels. The first level comprises of blood flow model and computation of endothelial shear

stress (ESS). The second level includes a minimum and maximum amount of lipoprotein models. The third level consists of LDL oxidation model, the formation of foam cells and differentiation of macrophages. A proposal compares computational results, including alteration in lumen diameter, the thickness of the arterial wall and plaque components. The multi-level model helps to increase the accuracy level of plaque development.

The concept of image segmentation suggests in the medical field for analysis, registration-based, 3D reconstruction. Due to fuzzy edges and complex structures, the quantitative investigation of CT image tends to be very difficult. Image segmentation method has better results and more significance in the field of auxiliary studies and clinical applications. The effect of carotid stenosis examined with the help of computer-based schemes [19]. Atherosclerosis affects coronaries, cerebral regions and carotids. Computational tasks have the firm capacity to simulate the plaque comprising of different geometries and specifications. According to X. C. Jin, S. H. Ong, and Jayasooriah, morphological operators such as dilation, erosion play an essential role in binary images [19]. The operators, in turn, helps to reduce the effect of noise, clump splitting and accurate detection of edges. Another simplified approach, which can overcome some limitations of binary images are erosion and dilation using reference points [20]. Reference points and coding methods carried out with morphological operators such as dilation and erosion. RPI algorithm considered to be more effective in case of worst situations and more supportive in case of real-time image processing.

B. Contribution of this work

In this paper, we propose the identification and classification of atherosclerotic plaque in the human heart. Accurate consideration of binary image represents atherosclerotic plaque and blood vessels accounted by using morphological operations and imaging techniques. Morphological operators include erosion and dilation, whereas imaging techniques used are pre-processing, segmentation and feature extraction. The following results simulated using Matlab software tool.

II. METHODOLOGY

This section describes the components and working of the corresponding model. Morphological operations play a vital role in a similar image. Morphological operators such as erosion and dilation help to remove unwanted background with the concept of image segmentation. Collect the CT image of a patient with a vulnerable atherosclerotic plaque and used as an input image. Read the image, which is in RGB form and convert it into a grey image. Collected images have preprocessed so that noise is removed and thresholding technique used for segmenting an image.

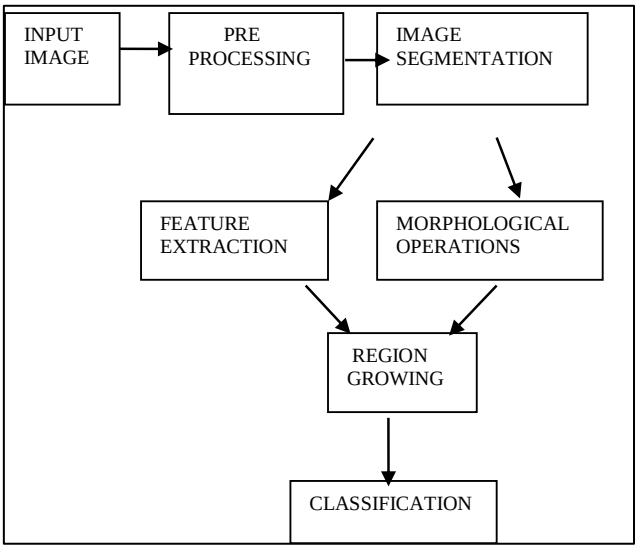


Fig 1: Procedure for identifying and visualising an image of atherosclerotic plaque.

The initial step involves preprocessing an input image, and the second step requires segmentation of an image to view in different postures. The third step comprises feature extraction and morphological operations, such as dilation and erosion. At last, the classification of atherosclerotic plaque visualised.

A. IMAGE PREPROCESSING

Image pre-processor is a common name used for operations at the lowest level of abstraction. Intensity images are input and output. Iconic images are the same kind of original data, which captured by the sensor. An intensity image usually represents by a matrix of image function values (brightnesses).

The aim is to improve the information of image that inhibits unwilling distortions or enhances some image features important for further processing. The geometric transformations of images (e.g. scaling, rotation, translation) are classified among pre-processing methods. Hence the same characteristic techniques used and the steps involved in image preprocessing described. Initially, an image converts into grey-scale image and filtering helps to remove unwanted noise from the given image. Finally, the method of binarisation takes place. The steps given below-

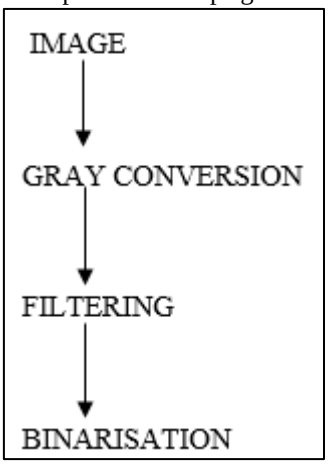


Fig 2. Steps involved in image preprocessing

B. IMAGE SEGMENTATION

An image partitioned into various regions based on features of pixel level in digital image processing. Image segmentation could involve separation of foreground from background or clustering regions of pixels based on similarities in color and shape. For example, a typical application of image segmentation in medical imaging is to detect and label pixels in an image or pixels of a 3D volume that constitutes tumour in a patient's brain or other organs.
Several algorithms and methods arose for image segmentation, which developed over the years. Segmentation problems help to clear certain application area by using the concept of domain-specific knowledge effectively. These applications include automated driving, video surveillance and machine vision, medical imaging.

C. FEATURE EXTRACTION

Feature extraction a type of dimensionality reduction. The main aim is to represent exciting parts of an image. The obtained image is similar to a compact feature. Feature extraction is useful when image sizes are around, and reduced feature representation is required. The tasks such as image matching and retrieval completed with the help of removal. Feature detection, feature extraction, and matching combine to solve common computer vision problems such as object detection and recognition, content-based image retrieval, face detection, identification, and texture classification.

Deep learning models used for automated feature extraction algorithms and other standard feature of extraction techniques include:

1) Histogram of oriented gradients (HOG)
2) Local binary patterns (LBP)
3) Haar wavelets
4) Colour histograms

III. RESULTS AND DISCUSSION

The identification and visualisation of atherosclerotic plaque implemented using digital image processing methods like image pre-processor, image segmentation, feature extraction, region growing. Morphological operators such as dilation and erosion play an essential role in visualising an image effectively. With the help of the median filter, a clear view of heart image obtained and identification of atherosclerotic plaque takes place. The values of threshold and signal to noise ratio simulated using matrix laboratory tool. This software delivers the visual appearance of blood vessels.

A. SIGNAL TO NOISE RATIO

Signal-to-noise ratio (SNR) implemented in imaging can characterise the quality of an image. The sensitivity of an imaging system described in terms of the signal level that yields a threshold level of SNR. SNR quantifies in decibels (dB) of signal power relative to noise power. An expression for SNR in terms of decibels by using the following formula,

SNR=10*log10(signal/noise)

Filtering technique implements to remove unwanted noise and improves the quality of an image. Median Filter plays an important role in this approach. It is a non-linear digital filtering technique, which often removes noise from an image. Such noise reduction improves the results of later processing.

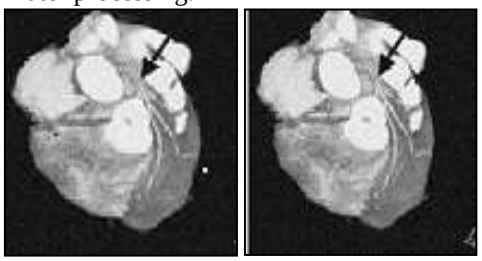


Fig. 3

The results of the model represent a clear binary image of a heart including blood vessels with a signal to noise ratio, where r=30.07 and r=28.08

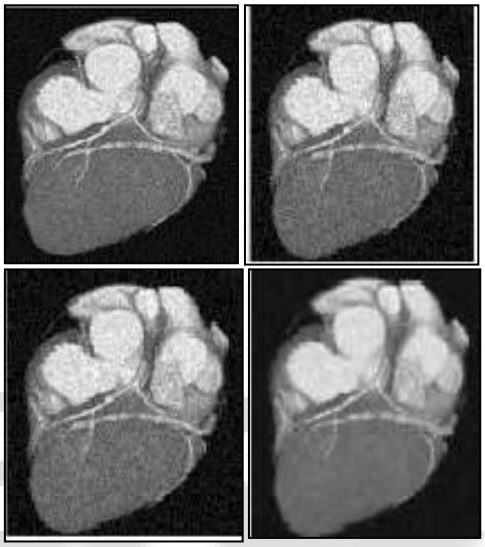


Fig. 4

The first row of an image undergone image segmentation and arteries, veins and capillaries viewed. The results of the model characterise the value of the signal to noise ratio, where r=28.02. Compared to fig 3, the amount of the signal to noise ratio gets reduced using a filtering method called a median filter.

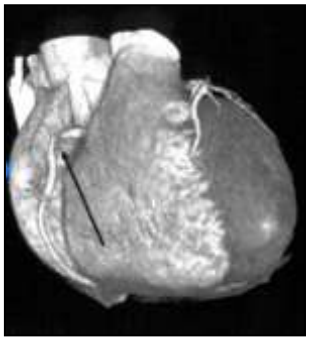


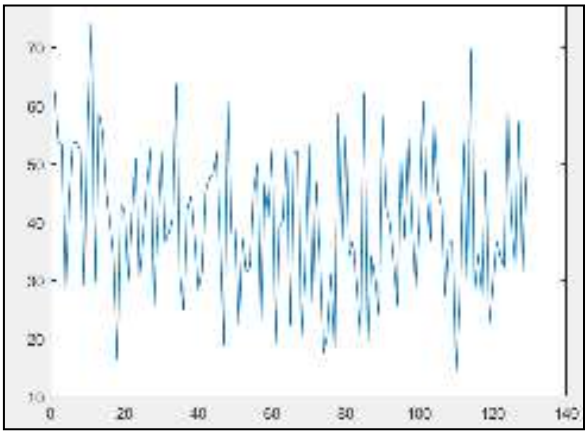
Fig. 5

The given result of an image represents the presence of atherosclerotic plaque with less value of the signal to noise ratio value.

B. THRESHOLDING

The primary role of Thresholding is to classify the pixel values in an image. Thresholding performs on greyscale images in which, a model has pixel values ranging from 0–

255. When the threshold shows on an image, the pixels classify by setting an upper and lower bound to each group. The threshold represented in graph format and plotted below.



IV. CONCLUSION

A method for identifying and visualising atherosclerotic plaque, which in turn leads to a severe heart attack proposed in this paper. An image validates with the help of morphological operators such as erosion and dilation. Some techniques such as image segmentation, feature extraction tends to obtain a clear view of an image. MATLAB plays an essential role in getting the results using simulation. In future, the survey based on the classification of atherosclerotic plaques present in heart identified using operators and simulation method.

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