Tracking of Blood vessels for Stenosis

SHANMATHI S
VAISHNAVI V
ROHINI S

Supervisor:Mrs P.Mirunalini
Assistant Professor
SSN College of Engineering, Chennai

April 8, 2015

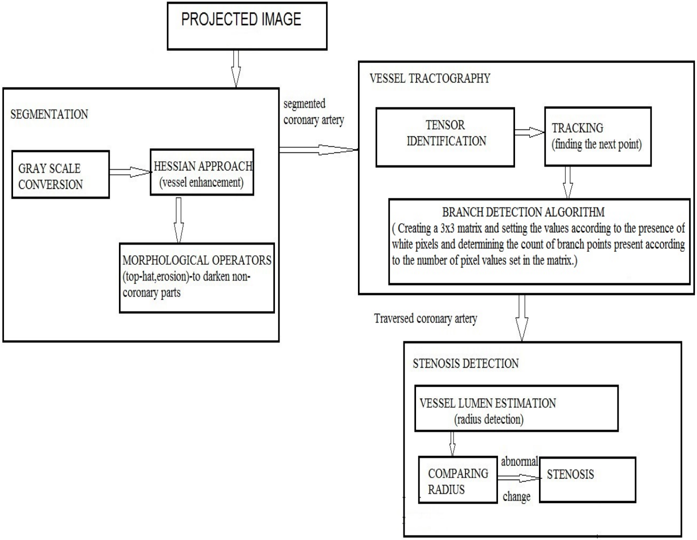
Introduction

- Medical Imaging is the technique to represent the interior body regions for medical analysis and diagnosis.
- In this work , a lethal disease called stenosis (i.e. abnormal narrowing of coronary artery) is detected.
- So an automated stenosis detection system is proposed which is used in computer aided diagnosis.

MODULES

- Segmentation- to segment the coronary arteries from the heart.
- Vessel tractography-to track along the blood vessels.
- Stenosis-identification.

ARCHITECTURE DIAGRAM



PREPROCESSING

- The input CTA(Computed Tomography Angiography) images are obtained from medical experts.
- This CTA image is in the form DICOM format(Digital Imaging and Communications in Medicine).
- Projection images in the DICOM format are converted to TIFF image such that no data is lost.i.e. these images are uncompressed to maintain the information.
- A special software called OSIRIX has been used to convert DICOM to TIFF format.

INPUT IMAGE

Figure: input image

SEGMENTATION

- 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
- This matrix describes the 2nd order image intensity variations around the selected pixels.
- In this technique first the hessian matrix has to be formed which is given by, 2×2 matrix

$$\begin{pmatrix} \mathrm{D}_{xx} & \mathrm{D}_{xy} \\ \mathrm{D}_{yx} & \mathrm{D}_{yy} \end{pmatrix}$$

- where the elements of the matrix are the second order derivatives of the gaussian function.

SEGMENTATION

- Gaussian function is used to define gaussian blur in image processing.i.e. it reduces the noise in the images.
- Gaussian function is given by,
  $g(x, y) = (1/\sigma\sqrt{2 * \pi}) * e^{-(x^2+y^2)/(2*\sigma^2)}$
    - where x and y represents pixel coordinates and sigma represents standard deviation.
    - Hessian matrix so formed for NxN matrix is reduced to 2x2 matrix using an inbuit function, cvReduce in OpenCV.

SEGMENTATION

- This matrix is then convoluted with gray scale image.
- The resulting output is the vessel enhanced image.
- Now morphological operator, top hat is applied to suppress the background image.
  - Top hat - erosion followed by dilation.
  - Erosion:remove pixels on object boundaries.
  - Dilation:add pixels to the object boundaries.
- Thresholding is applied to the resultant top hat image.
- Skeletonisation is then applied to the resultant image to get the centerline of the vessels for tracking purposes.

SEGMENTATION

- RESULT IMAGE AFTER HESSIAN BASED APPROACH

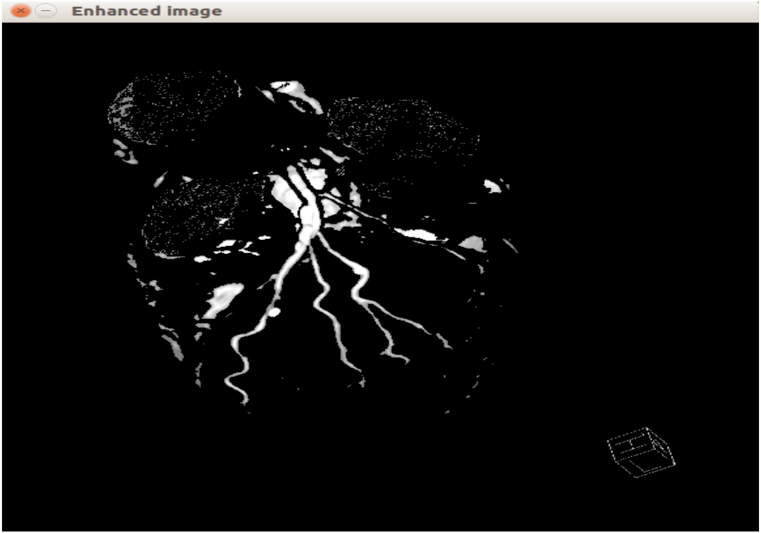


Figure: ENHANCED IMAGE

SEGMENTATION

- RESULT IMAGE AFTER TOP HAT IS APPLIED

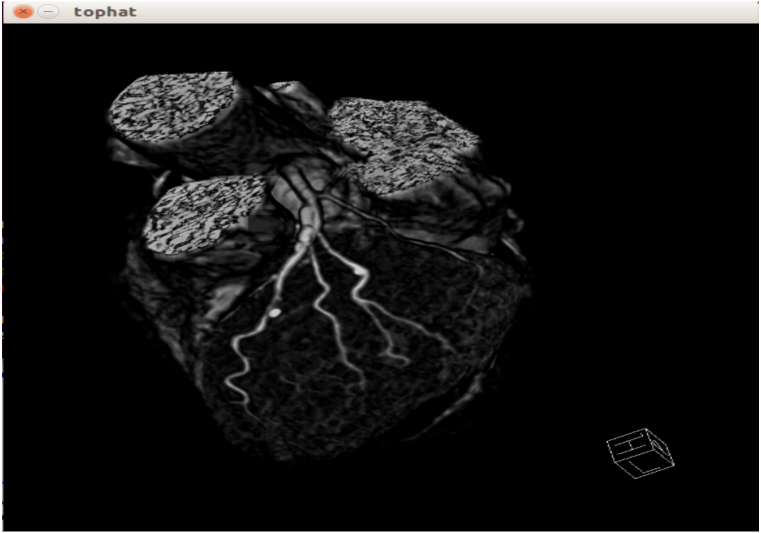


Figure: TOPHAT IMAGE

SEGMENTATION

- RESULT IMAGE AFTER THRESHOLDING

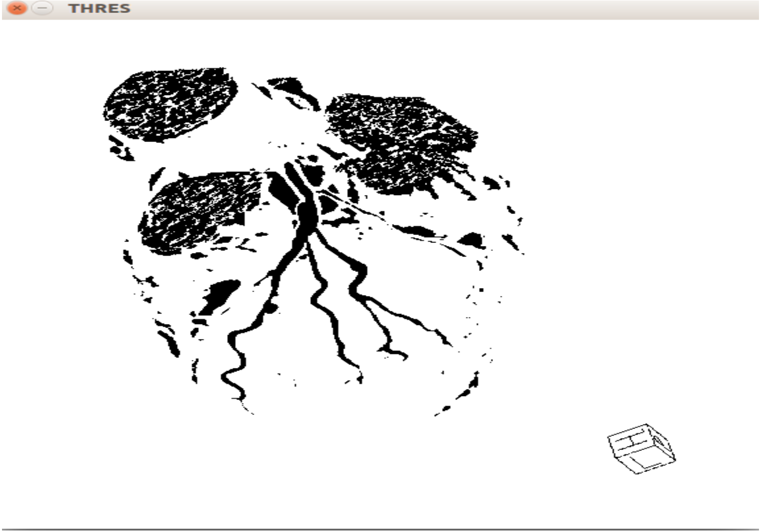


Figure: THRESHOLDED IMAGE

SEGMENTATION

- SEGMENTED BLOOD VESSELS AFTER FINDING CONTOURS

Figure: SEGMENTED BLOOD VESSELS

SEGMENTATION

- RESULTANT IMAGE AFTER SKELETONISATION

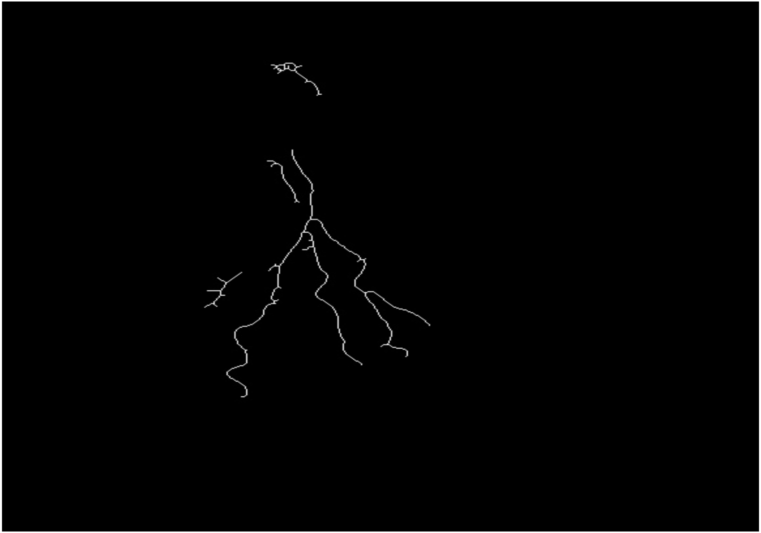


Figure: SKELETONISED VESSELS

VESSEL TRACTOGRAPHY

- Traversing through blood vessels in coronary artery is done using vessel tractography method.
- Here we traverse through the centerline of the vessel.
- For that first find the seed(intial) point using contour function.
- Then the direction of the consecutive points can be found using intensity based tensor method.

VESSEL TRACTOGRAPHY - INTENSITY BASED TENSOR CREATION

- To construct a tensor, create a circle enclosed in a rectangle.
- With the seed point as center, draw a circle of best fit radius.
  - DETERMINING RADIUS OF THE CIRCLE TO FIT IT IN THE VESSEL
    - 2-NORM ($d^t * d$) of tensor matrix is found.
    - From the resultant matrix of $d^t * d$, maximum eigen value (Λ_{max}) can be found.
    - d^t is the transpose of tensor matrix d.

$$\begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix}$$

.

    - The square root of Λ_{max} is found.
    - This procedure is carried out for different radius values (r_{min} to r_{max}).
    - The radius value for which Λ_{max} is maximum, is set as the radius of the circle for the considered point.
- construct three rectangles of which one is vertical and the other two rotated at given angles.

VESSEL TRACTOGRAPHY - INTENSITY BASED TENSOR

- CALCULATING INTENSITY MEASUREMENT M_i $M_i = (\mu\Omega_1 - \mu\Omega_2)^2$
  - ★ Ω_1 is the region of the circle.
  - ★ Ω_2 region of the (rectangle-circle) area.
- M_i is the square of (mean intensity of circle - mean intensity of (rectangle-circle) area).
- Calculate $M_i$in three directions.
- The resulting matrix is a column matrix of order 3x1.

$$\begin{pmatrix} M_1 \\ M_2 \\ M_3 \end{pmatrix}$$

.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- INTENSITY CALCULATION FOR CIRCULAR AND RECTANGULAR REGIONS
  - TO GET THE INTENSITY MEAN OF THE CIRCLE:
    - ★ Find points along the circumference of the circle.
    - ★ Consider the circle to be two semi circles.
    - ★ Using circumference points of the upper semicircle and the lower semi circle,traverse line by line covering the entire region of the circle and thereby finding the intensity of the entire circle.
    - ★ The intensity values obtained from the previous step are added and is divided by the total number of pixels inside the circle which gives the intensity mean of the circle.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- TO GET THE INTENSITY MEAN OF THE RECTANGLE:
  - ★ Using the vertices and points on the perimeter of the rectangle,traverse line by line to cover the entire region of the rectangle and thereby finding the intensity of the entire region.
  - ★ The mean intensity values of the regions are calculated accordingly.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- DETERMINING ORIENTATION VECTORS:
  - Find the point on the circumference of the circle at angle with which the rectangle has been rotated with respect to the circle.
  - Subtract this value from the center point of the circle to get the direction vector.
  - The same process is done for the rest of the two directions.
  - Orientation vectors along the three directions g_1, g_2, g_3 are obtained.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- H MATRIX CONSTRUCTION:
  - The intensity mesurement can be modelled as
  - $Mi = g_i^T * D * g_i$
  - This equation is rearranged to $Mi = H_i * d$
  - Using values of orientation vectors g_1, g_2, g_3 H matrix can be constructed.
  - The *H Matrix is of order* 3×3 matrix

$$\begin{pmatrix} g_{1x}^2 & g_{1y}^2 & 2g_{1x}g_{1y} \\ g_{2x}^2 & g_{2y}^2 & 2g_{2x}g_{2y} \\ g_{3x}^2 & g_{3y}^2 & 2g_{3x}g_{3y} \end{pmatrix}$$

.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- TENSOR MATRIX CONSTRUCTION:
  - Tensor matrix is constructed using formula $d = (H^T H)^{-1} H^T M$
  - The resulting matrix is of order 3*1.

$$\begin{pmatrix} d_{11} \\ d_{22} \\ d_{12} \end{pmatrix}$$

.

  - Since tensor matrix D is symmetric , the tensor matrix of order 2x2 can be constructed.

$$\begin{pmatrix} d_{11} & d_{12} \\ d_{12} & d_{22} \end{pmatrix}$$

.

VESSEL TRACTOGRAPHY - CREATING TENSOR

- Single Value Decomposition method is used to obtain non-negative eigen values and corresponding eigen vectors.
- The corresponding vectors of the least eigen value is added with the seed point to determine the next position along the vessel.
- This method is repeated till all vessel branches are traversed.

VESSEL TRACTOGRAPHY

- TENSOR CONSTRUCTION - CIRCLE AND RECTANGLES

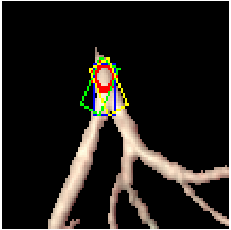


Figure: TENSOR CONSTRUCTION

BRANCH DETECTION ALGORITHM

- Segmented blood vessels are reduced to unit width pixel.
- A method is newly created to detect the presence of branches and its count.
- In this method a 3x3 matrix is created at a point considered.
- The values in the matrix are set accordingly by determining the presence of white pixels.
- To search for those points where there is a split, using the 3 x 3 pixel neighbourhood, we search to see if the total number of white pixels is 4 or more.
- If that is the case, the centre of the neighbourhood is a potential branch point.
- If the count is three, this means that we are following along the skeleton.
- If the count is two, then this is an end point.

STENOSIS

- 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.

VESSEL TRACTOGRAPHY

- RESULTANT IMAGE AFTER DETECTING STENOSIS

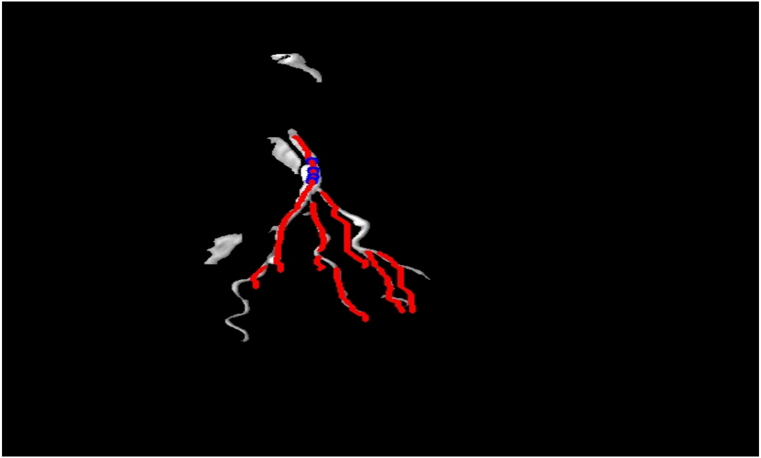


Figure: STENOSIS

PERFORMANCE ANALYSIS

- The system was evaluated based on the ground truth obtained from experts for stenosis detection.
- To evaluate the performance of the proposed system, we have used precision, recall and F1 score as evaluation criteria.
- True Positive(TP): if case is positive and prediction is positive.
- False Positive(FP): if case is negative but prediction is positive.

$$Precision(p) = \frac{TruePositives}{\text{True Positives + False Positives}} \tag{1}$$

$$Recall(r) = \frac{TruePositives}{\text{Total number of positive samples}} \tag{2}$$

$$F1Score = \frac{\text{2 x p x r}}{\text{p + r}} \tag{3}$$

PERFORMANCE ANALYSIS

Table: PERFORMANCE EVALUATION

Patient	Positive cases	Positive predictions	True Positive	False Positive	Precision	Recall	F1 Score
P1	2	2	2	1	0.66	1	0.79
P2	1	1	1	1	0.5	1	0.66
P3	3	3	3	2	0.6	1	0.75
P4	2	2	1	1	0.5	0.5	0.5
P5	5	4	3	0	1	0.6	0.75
P6	4	3	2	0	1	0.5	0.66
P7	7	6	5	2	0.7	0.71	0.70

References

- Alejandro F. Frangi, Wiro J. Niessen, Koen L. Vincken and Max A.Viergever (2006) ‘ Multiscale vessel enhancement filtering in Image Sciences Institute’, vol no.1496, pp 130-135.
- Anindya Sen, Li Lan, Kunio Doi, and Kenneth R. Hoffmann (1999) ‘Quantitative evaluation of vessel tracking techniques on coronary angiograms’, Medical Physics, vol. 26, no. 5, pp 698-705.
- Aqeel Al-Surmi, Rahmita Wirza, Ramlan Mahmod, Fatimah Khalid and Mohd Zamrin Dimon (2014)‘ A new human heart vessel identification, segmentation and 3D reconstruction mechanism ’, pp 1-4.
- Ilkay Oksuz ‘Multi-scale Hessian based approach for segmentation of lung vessel tree in 3-D CTA data ’, pp 1-2.
- Marcin Rudzki (2009) ‘Vessel Detection Method Based on Eigenvalues of the Hessian Matrix and its Applicability to Airway Tree Segmentation’, pp 100-105.

- P. Echevarria,T. Miller and J.O'Meara (2004) 'Blood Vessel Segmentation in Retinal Images', Journal of Cardiothoracic Surgery, 9:161, pp 1-9.
- Suheyla Cetin , Ali Demir, Anthony Yezzi, Muzaffer Degertekin, and Gozde Unal (2012) , 'Vessel Tractography Using an Intensity based Tensor Model with Branch Detection', IEEE transactions on medical imaging, vol no. 32, no. 2, pp 1-6.
- V. Grau, A. U. J. Mewes, M. Alcaniz,R. Kikinis and S. K. Warfield (2004) 'Improved Watershed Transform for Medical Image Segmentation Using Prior Information', vol. 23, pp 2-6.

THANKYOU