International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V70I6P237

Volume 70 Issue 6, 366-378, June 2022

Original Article

Advanced Computational Method to Extract Heart Artery Region

K. Kavipriya[1], Manjunatha Hiremath[2]

[12]Department of Computer Science, Christ Deemed to be University, Bangalore, Karnataka, India.

[1]kavipriya.k@res.christuniversity.in

Received: 03 April 2022 Revised: 30 May 2022 Accepted: 11 June 2022 Published: 30 June 2022

Abstract- *Coronary artery disease, also known as coronary heart disease, is the thinning or blockage of heart arteries, which is generally caused utilizing the build-up of fatty material called plaque. The coronary angiogram test is currently the most utilized method for identifying the stenosis status of arteries in the heart. The objective of the proposed hybrid segmentation method is to extract the artery region of the heart from angiogram imagery. Numerous angiogram video clips have been considered in the dataset in this research work. These video clips were acquired from a healthcare center with the due consent of patients and the concerned healthcare personnel. Most angiogram videos consist of unclear images, or the contents are generally not clear, and medical experts fail to acquire accurate information about the damages or blocks formed in arteries due to the same reason. A hybrid computational method to extract well-defined images of heart arteries using Frangi and motion blur features from angiogram imagery has been proposed to address this issue. Fifty patients' information has been used as the dataset for experimentation purposes in this research work. The enhanced Frangi filter is used on the dataset to obtain edge information to enhance the input image based on the Hessian matrix.*

Further, the motion blur helps in automatically tracking/tracing the pixel direction using the optical flow method. In this method, the complete structure of the artery is extracted. The results, when compared to the existing methods, have proven to be novel and more optimal.

Keywords*-Coronary Angiogram, Artery, Stenosis, Segmentation, Frangi Filter, Motion Blur.*

1. Introduction

The cardiovascular system plays an important role in living organisms. Transferring or supplying material that supports the most important processes required for life to various organs of the body and tissues and expelling metabolic waste are some of its most important functions [1]. Moreover, it plays a vital role in regulating oxygen and nutrient distribution under various physiological states. The coronary artery distributes oxygenized blood and nutrients to cardiac muscles [2]. When calcium or other fatty materials get deposited in the walls of arteries, they become narrower, thereby falling the blood flow to the cardiac muscles, which results in cardiac arrest or heart attack. Generally, physicians make use of angiogram tests to diagnose cardiac diseases.

An angiogram is a technique that uses X-ray contrast imaging to look at the arteries in the human body. In an angiogram test, a catheter is inserted into a patient's wrist or groin [3], slowly threading through the artery. Once it reaches the exact location within the body, a dye is inoculated inside the catheter and spreads over the artery. Parallelly, images are captured using different medical imaging techniques, including X-ray, CT, and MRI. X-ray [4] is considered the best method for detecting coronary artery disease among these various imaging techniques. During an angiogram test, the images are captured by the X-ray machine at different angles and are stored as different frames. Only doctors specializing in angiogram testing techniques can diagnose stenosis in arteries from angiogram videos. Identifying coronary diseases from coronary angiogram images is challenging because of the various elements in the image. Medical image processing helps in analyzing images with ease. By using preprocessing techniques, the noise elements in images are removed. The heart artery region of interest in medical images can be extracted and analyzed using segmentation techniques. It has been found that identifying the structure of the artery (region of interest) from the coronary angiogram image is clinically essential. The proposed method uses image processing techniques and segmentation methods to remove noise and extract the structure of arteries, which is instrumental in other processes like detecting and recognizing blockages. A hybrid segmentation method is proposed to extract the specific artery region from angiogram images that help doctors identify stenosis in the arteries. This research work presented in this paper has been divided into six sections. The first section gives a brief introduction to the research area.

In contrast, the second section discusses the various existing methods used to extract segments from images and the research gap. The third section defines the materials and methods for processing and presenting the dataset. The third section discusses the proposed research methodology, while the fourth section presents the analysis of results obtained from implementation. In the final section, the conclusion has been discussed.

2. Literature Review

In cardiology, identifying the accurate structure of blood vessels and the right level of stenosis is very important. Research on coronary artery disease has made prodigious growth over the years. Researchers have proposed many methods where different image processing techniques are implemented for more efficient detection of stenosis in coronary arteries. In [5], a new approach for automatic identification of coronary artery veins from angiogram imagery has been suggested. The proposed identification model implements the multiscale with Gabor filters for improved efficiency over other up-gradation methods constructed using the Gaussian matched and multiscale Hessian techniques. By a test set of forty angiogram images, this segmentation method achieved an accuracy of 0.952. A thresholding technique based on a multiobjective optimization method was also proposed in the model, and this was compared with seven different thresholding techniques. The technique got an average performance rate of around 0.881. However, the proposed research work does not focus on extracting a region of interest images alone. The extraction leads to average performance, which is not optimum in this research work.

In [38], a heart artery region segmentation method premises on Gaussian matching filters (GMF) and the second-order vessel size derivatives have been proposed. Enhancement techniques using genetic algorithms have been proposed in this research work to obtain optimal performance. Inter-class variance thresholding is used for segmentation. However, this technique is neither linear nor optimal. The proposed model demonstrated notable performance with an accuracy of 0.962 for a dataset of 20 angiogram images with variable specifications. However, there is a research gap in the proposed model regarding the normalization and rectification of the region of interest.

An automated segmentation method for extracting coronary blood vessels from 3D cardiac CTA (CCTA) has been proposed in [7]. The research presents an amalgamation of various technologies for segmentation that consist of multi-atlas, multiscale vascular enhancement, morphological techniques, and other methods. A Gaussian-based pyramid model employed for registration efficiency has also been proposed in the research work. The 3D multiscale vessel method is applied for enhancement purposes. Although the proposed method is the most robust, the method cannot be recommended since the execution complexity is higher when compared to other methods.

The research work in [8] helps recognize the tabular structures for specifying the appearance of arteries. A qualitative extraction of the region of interest from the images was proposed. However, the research work failed to present the accuracy of the outcome.

The method from [9] presents a novel technique for blood vessel segmentation via the optimization approach with differential evolution. The suggested method has been evaluated using a training dataset of 40 angiogram images and a testing dataset of 40 angiogram images using different segmentation methods. The suggested method used a single-scale technique with a Gabor filter to improve the blood vessels within the images. The method attained an accuracy value of 0.9423 using a dataset of angiogram images. However, the research work does not attempt to normalize artery structure from the images.

In [10], a segmentation method formed on selective feature mapping for the left artery from angiogram images has been proposed. The proposed method presents two phases. First, a candidate area is generated and then segmented using a neural network. This segmentation method was compared with U-Net by considering five criteria: precision, recall, specificity, F1 score, and accuracy. However, the method failed to consider the smaller artery since it mainly concentrated on the main left artery.

In [11], a method to improve the feat rate of segmentation region in angiogram images has been proposed. The structural position of the artery is identified using foreground detection techniques in angiogram image sequences. Blood vessel determination methods and thresholding techniques that help in artery region segmentation are applied to the angiogram image sequences with a resolution of 512 x 512 and between 120 to 150 frames. Using Frangi and Otsu methods, the results yielded an accuracy of 93.81. However, the region of interest extracted from the angiogram images in this research is sub-optimal.

In [12], a segmentation algorithm that extracts vascular images from coronary angiogram images has been proposed. The proposed method was assessed using a test dataset of 40 angiogram images. The Jaccard index and sensitivity values are better when compared to other performance metrics. The artery regions segmented from the angiogram images lack clarity. By analyzing the various research methods that have been proposed, it has been observed that coronary artery region extraction needs a precise method for the extraction of the region of interest.

3. Methodology

3.1. Materials and Methods

For the proposed research work, the dataset was collected manually. The dataset was captured from 2019 to 2021 at the Raghavendra Hospital, Madurai, with the due consent of both doctors and patients. A total of fifty subjects' medical data has been used for testing and implementation purposes. The subjects were well-informed in detail about the research study and its outcome. The data was collected upon receiving approval from the medical ethical committee. Specific measures have also been implemented to avoid disclosing the patients' personal information. The research work considers only each patient's medical data, and this data is connected to only an ID tag.

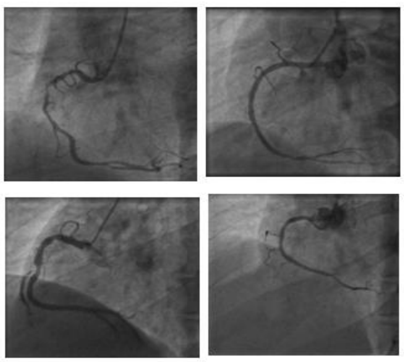


Fig. 1 The sample image dataset collected

The medical data was made available in a video format. This video format is a collection of multiple exposures of X-ray angiogram images. The C-Arm X-ray machine, an advanced medical imagery device that works on the basic foundation of X-ray technology, was used to capture the image dataset. This machine is a variant of the fluoroscopy machines and is called an image intensifier. The C-Arm X-ray machine converts X-rays into strong visible light better than other ordinary screens. A medical practitioner then rotates this device at different angles to obtain images from various angles. A sample of the collected dataset images is presented in Fig. 1.

The proposed research work focuses on extracting artery regions of the human heart from the angiogram images. To achieve this, angiogram video clips have been used. The current research work has been split into two distinct stages. This first stage deals with keyframe extraction, while the second stage concerns preprocessing and segmentation.

3.2. Keyframe Extraction

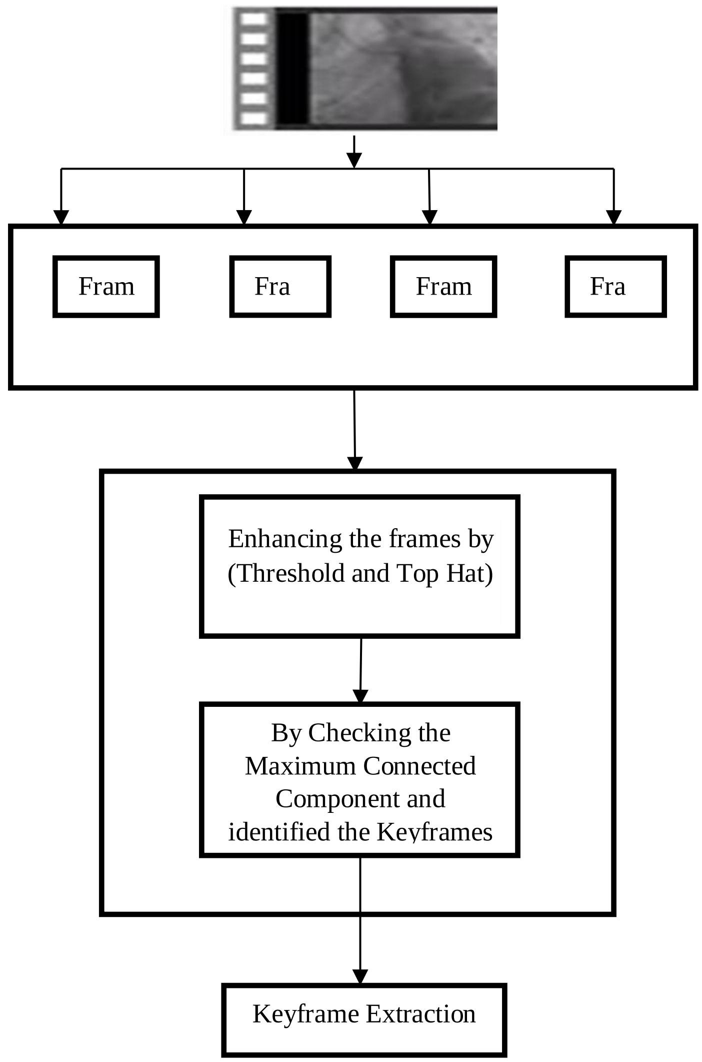


Fig. 2 The proposed keyframe extraction method

In any data in the form of a video, a keyframe is a point or an image from the video that defines the initial and ending points of any transition. These are termed frames since their position in time is calculated in frames arranged as a strip of film or on a digital video editing timeline. The term 'keyframe' indicates how the frame independently modifies the parameter values in a video clip.

Key-frames contain the most information compared to other frames in a video [13]. The proposed keyframe extraction method is shown in Fig. 2. In the first step of this method, a video is provided as input. In the second step, the video is split into different frames [14]. Then, the frames are enhanced using threshold [15] and morphological operations [16]. Once the frames are enhanced, the highest connected component in each frame is calculated and identified as the keyframe. It is the keyframe extraction method that is used for the detection of keyframes in angiogram videos.

3.3. Segmentation

Segmentation is a sub-task of image processing mainly used for partitioning an image into different regions per the requirement. We can generally state segmentation as extracting a specific region from the input image. The extraction is made on some requirement or objective. The primary priority of image segmentation is to simplify the pattern recognition process by considering the extracted region of interest. In the current study author considered two main image segmentation methods, namely (a) Enhanced Frangi and (b) Motion blur-based segmentation; the segmentation methods are explained in detail in the following sections:

3.3.1. Enhanced Frangi Method

The Frangi method [17][18] is usually used to extract curvilinear structures from images. The Frangi method proposed in this research involves the Hessian Eigen values-based method [37] to extract the artery structure from the input images. By using this method, the non-artery regions are automatically suppressed from the angiogram images. An explanation for the Frangi method proposed in this research method has been provided.

Primarily, a Gaussian filter(x,y) [20] is applied to an angiogram image to lessen the noise from the input image. The normal Gaussian filter is defined as:

$$G(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \quad (1)$$

Where σ = standard deviation

$G(x,y) =$ Gaussian filtered image

The strength and direction of an artery can be considered using the Eigenvalues from the Hessian matrix and Eigenvectors from the Hessian matrix [21] because the Hessian matrix stands as a symmetric matrix of the second-order partial derivation of the image function [22].

The partial derivatives are considered pixel intensity variances in the neighborhood pixels [23].

$$H = \begin{bmatrix} I_{xx} & I_{xy} \\ I_{xy} & I_{yy} \end{bmatrix} \quad (2)$$

Where H is a Hessian matrix

From the above equation, by using the I_{xx} and I_{yy} K value is calculated.

$$K = (I_{xx} + I_{yy})/2 \quad (3)$$

From the above, by using the I_{xx} , $I_{xy}$and I_{yy} Q value is calculated.

$$Q = \sqrt{I_{xx}I_{yy} - I_{xy}I_{xy}} \quad (4)$$

From the Hessian matrix, Eigenvalues λ1 and λ2 are calculated.

$$\lambda_1 = K + \sqrt{k^2 - Q^2} \quad (5)$$

$$\lambda_2 = K - \sqrt{k^2 - Q^2} \quad (6)$$

λ1 and λ2 Eigenvalues are calculated [24] using the equations (5) & (6).

Vessel structure is extracted [25] using the below equation.

$$\upsilon(\sigma) = \begin{cases} 0 & if \quad \lambda_2 > 0 \\ \exp\left(-\frac{R_B^2}{2\beta^2}\right)\left(1 - \exp\left(-\frac{S^2}{2c^2}\right)\right) \end{cases} \quad (7)$$

Where, $R_B = \frac{\lambda_1}{\lambda_2}$,

$$S = \|H\|_F = \sqrt{\lambda_1^2 + \lambda_2^2}$$

In equation (7), parameters β and c are considered as thresholds that regulate filter sensitivity to R_B And S, respectively [26].

Table 1. Eigenvalues of the hessian matrix

λ_1	λ_2	Pattern and structure of the artery
N1	N1	Noisy, no preferred direction
L1	H1-	Bright artery structure
L1	H1+	Dark artery structure
H1-	H1-	Bright Blob-like structure
H1+	H1+	Dark Blob-like structure

In Table 1, H1 represents the highest value of magnitude and L1 represents the lowest magnitude. H1+ denotes H1 > 0 and H1- denotes H1 < 0. By using the pattern in Table 1, arteries are extracted from angiogram images. Once the foreground is extracted from the angiogram images, the arteries are not visible properly; therefore, the brightness of the filtered image increases. The contrast of the segmented image was enhanced to differentiate the artery. The Top-hat morphological operation [27] was used to improve the clarity of the artery region.

3.3.2. Motion Blur-based Segmentation Method

This segmentation method consists of the motion blur technique with entropy thresholding [28]. In this method, the motion blur-based filter is implemented constantly to interpret the angiogram image through Len1 and T, where Len1 is the trainable parameter, and T is the angle degree.

Algorithm for Motion Blur-based Segmentation Method

```
Input = Image
Output = segmented Image
Begin
    Read_Image
    GrayImage=RGB_Gray (Image)
    For T= 30:360:30 do
        Blurred_Image_eg=motionblur (Len1, T);
    End
    G1=Blurred_Image_eg - GrayImage;
    A1=imadjust(G1);
    Thresh=EntropyThreshold(G1)
    Return binarize(G1,Thresh)
End
```

The filter is rotated from a 30-degree angle across 360 degrees to extract the artery structure. Then, the blurred image is subtracted from the original angiogram image. The subtracted image is then converted to binary form by the entropy thresholding method [29]. This method will remove the non-artery region and retain the artery region from an angiogram image.

3.3.3 Proposed Hybrid Segmentation Method

In this research, a computational method to extract arteries from angiogram images has been proposed. Initially, the Enhanced Frangi Method was implemented where the Gaussian filter technique was applied to reduce the image noise. Then, the Hessian matrix is formed using the second-order derivatives of the image. The vessel structures are extracted from the angiogram images by examining the Eigenvalues. Parallelly, the motion blur is applied to the original input image. Blur kernel has been used to identify the region of interest, and an entropy thresholding technique has been used to convert the image into binary. The results obtained from the Enhanced Frangi method have background noise, and the artery is not visible in the results obtained using the motion blur filter. Therefore, the outputs from the Enhanced Frangi and motion blur methods were superimposed to produce better results. The superimposed images were stored, and the image edges were sharpened to enhance their clarity. The connected components in the images were calculated. The artery regions were segmented in this method by using the connected co mponent properties and the neighboring pixels. Fig. 3. shows the proposed hybrid segmentation method.

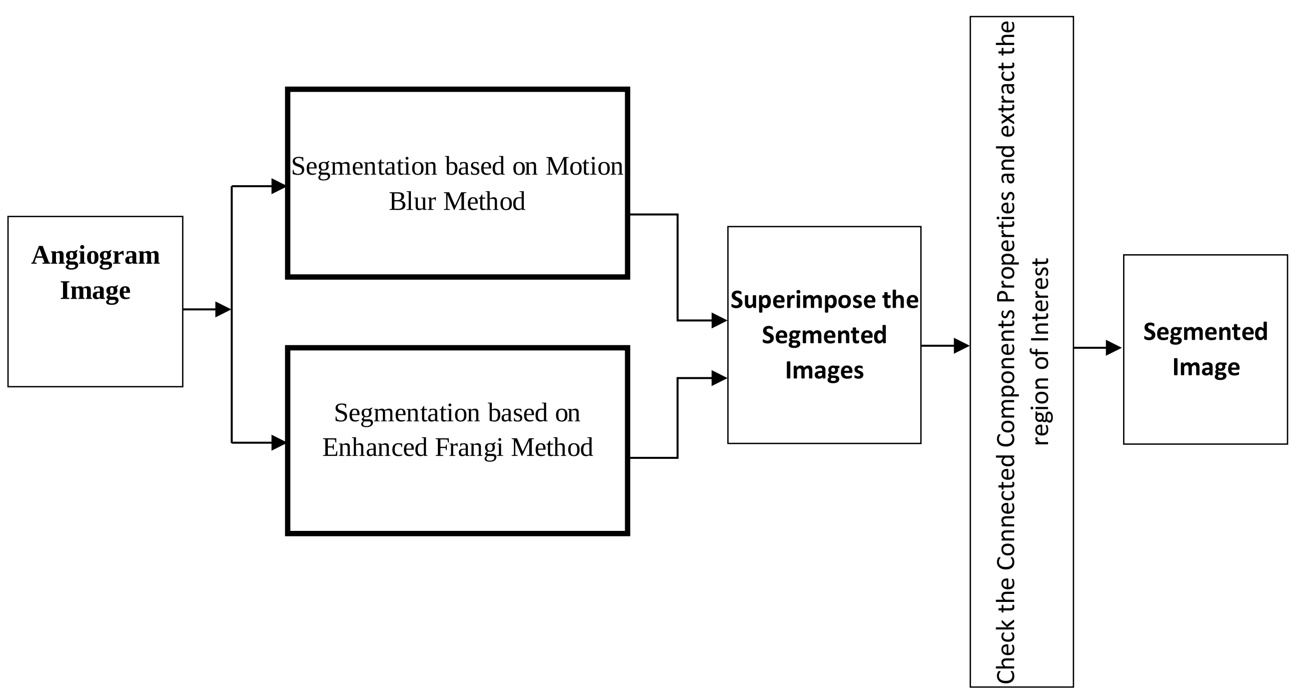


Fig. 3 Proposed hybrid segmentation method

The proposed hybrid segmentation procedure has been explained using the pseudocode discussed below.

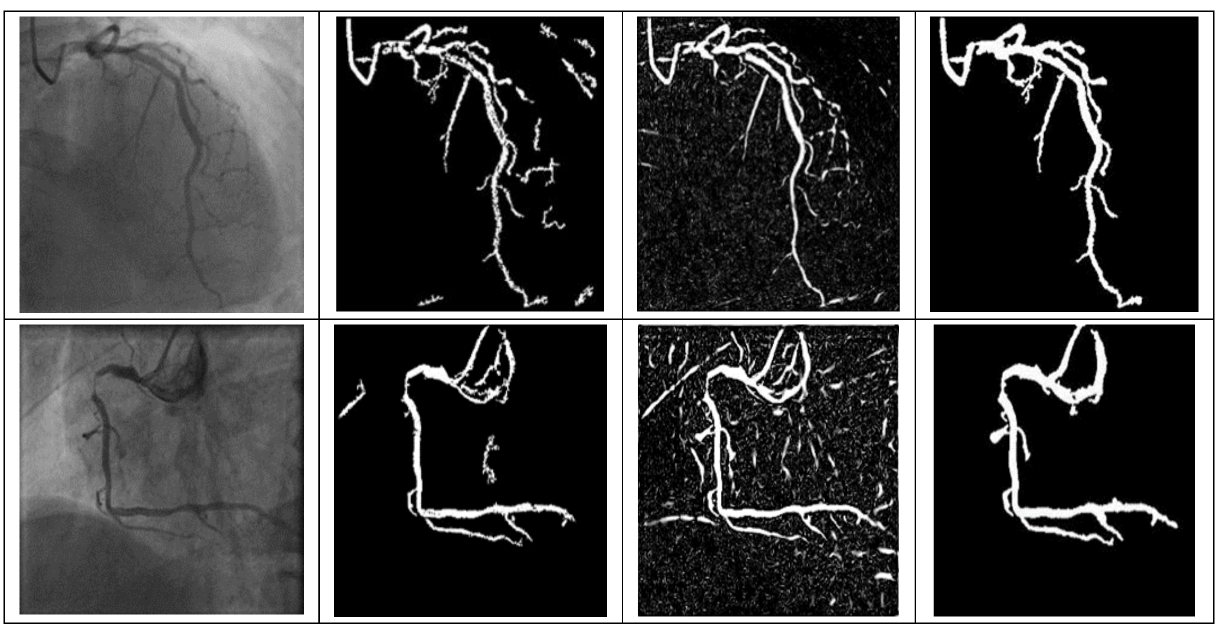
Procedure: Proposed Hybrid Segmentation Method
Input: Image (Keyframe)
Output: Segmented image
Phase 1: Angiogram Image Acquisition and Preprocessing
Step 1: Read the angiogram input images of size $m \times n$
Step 2: The input angiogram images are converted into grayscale images
Step 3: Noise extant in the images is removed using a Gaussian filter
Phase 2: Extract the Artery Structure Using Enhanced Frangi Method
Step 4: Apply partial derivation on the preprocessed images
Step 5: Then apply second-order partial derivation
Step 6: Convolute the preprocessed images with the second-order partial derivation
Step 7: Calculate the Eigenvalues
Step 8: By analyzing the Eigenvalues, the artery structure in the images is extracted
Phase 3: Extract the Artery Structure Using Motion Blur-Based Segmentation Method
Step 9: Parallelly, the input images are sent to the Motion blur-based segmentation method
Step 10: In the Motion blur method, by using the PSF and by rotating the Len at different angles, artery regions are extracted
Phase 4: Segmenting the Artery Region
Step 11: Outputs from the Enhanced Frangi and the motion blur-based filter are superimposed and stored as variables
Step 12: Sharpen the images to highlight the artery
Step 13: Convert the fused images into binary and calculate the connected components
Step 14: By checking the neighborhood pixel, the region of the heart artery in the images is extracted
Step 15: Display the resulting image

4. Result Analysis

The proposed hybrid method has been evaluated and deliberated. The software used for implementing the current research work was MATLAB. The dataset used in this research contains 50 X-ray coronary angiogram images of 300x300 pixels.

Fig. 4 shows the results obtained from implementing the proposed research model. Fig 4 (a) represents the original images from the dataset. It can be noticed that the original images have high noise, and extraction of the region of interest cannot be carried out with ease.

Experimentation was carried out using three different segmentation methods, and their results are shown in Fig 4 (b), (c), and (d). Fig 4 (b) denotes the results of the Motion blur-based segmentation method, while Fig 4 (c) represents the result of the Enhanced Frangi method. Fig 4 (d) represents the outcomes of the proposed hybrid segmentation method. In this research work, two existing segmentation methods were compared with the proposed hybrid segmentation method to gauge the accuracy of the region of interest in the images.



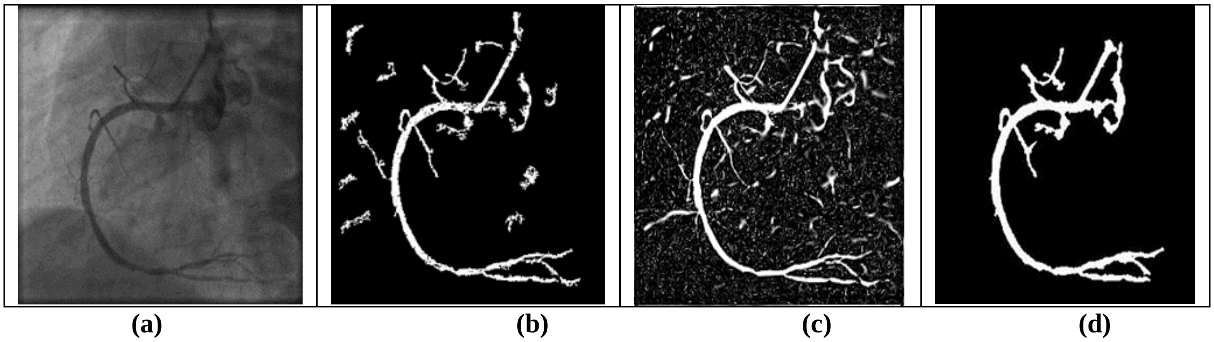


Fig. 4 Various Segmentation Resultant Images (a) Original Image (b) Motion Blur-based Segmentation Method (c) Enhanced Frangi Method (d) Proposed hybrid Segmentation Method

Table 2. Comparing the pixel accuracy for foreground and background in the angiogram image using the proposed and comparative methods

Sl.No	Method	P	N
1	Motion Blur based segmentation method	88.58	92.52
2	Enhanced Frangi method	91.14	59.49
3	Proposed segmentation Method	**95.75**	**92.92**

The evaluation of the proposed and existing techniques is represented in Table 2. The values of foreground accuracy and background accuracy of the final coronary angiogram images achieved using the proposed segmentation method and the existing methods have been used for comparison. Variable **P** stands for the artery region accuracy, and **N** stands for background accuracy. Here, the foreground accuracy for the proposed segmentation methods is 95.75, which is the highest compared to the other segmentation methods. The proposed segmentation method also reproduced images of the complete structure of the artery when compared to the existing segmentation methods.

The performance of the proposed technique has been evaluated. The accuracy measure is generally used as the important measure for evaluating the classification problem [30], and it is calculated by the extracted region pixels concerning the total number of pixels in the angiogram image as follows:

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \quad (8)$$

Where TP and TN are correctly extracted artery and non-artery pixels, respectively FN and FP are the incorrectly extracted artery and non-artery pixels. Sensitivity and specificity are also calculated using ,TN, FN, and FP. Sensitivity and specificity measures are the ratio of the artery and non-artery pixels, respectively. Table 3. list the performance levels of the different segmentation methods. The accuracy of the proposed segmentation method is 0.97, the specificity is 0.99, and the sensitivity is 0.87. The proposed method has a high segmentation accuracy compared to other methods. Fig. 5 shows the graphical evaluation of the accuracy comparison of the proposed and the existing techniques. Fig. 6 and Fig.7 show the graphical evaluations of the specificity and sensitivity metrics, respectively.

Table 3. Performance Comparison Results

Method	Accuracy	Specificity	Sensitivity
Ivan et al. [5]	0.92	0.93	0.85
Cruz-Aceves et al.[31]	0.95	0.96	0.82
Cervantes et al. [32]	0.96	0.98	0.63
Proposed Segmentation Technique	**0.97**	**0.99**	**0.87**

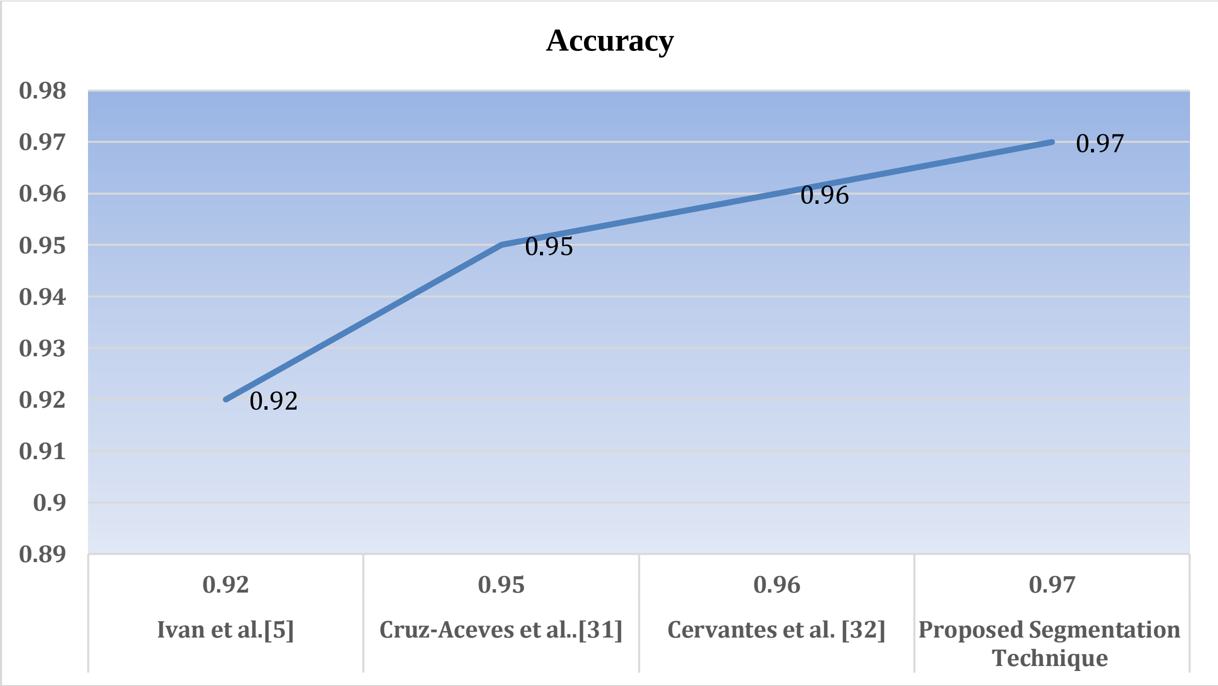


Fig. 5 Line plot comparison of accuracy with the proposed hybrid segmentation method and state-of-the-method

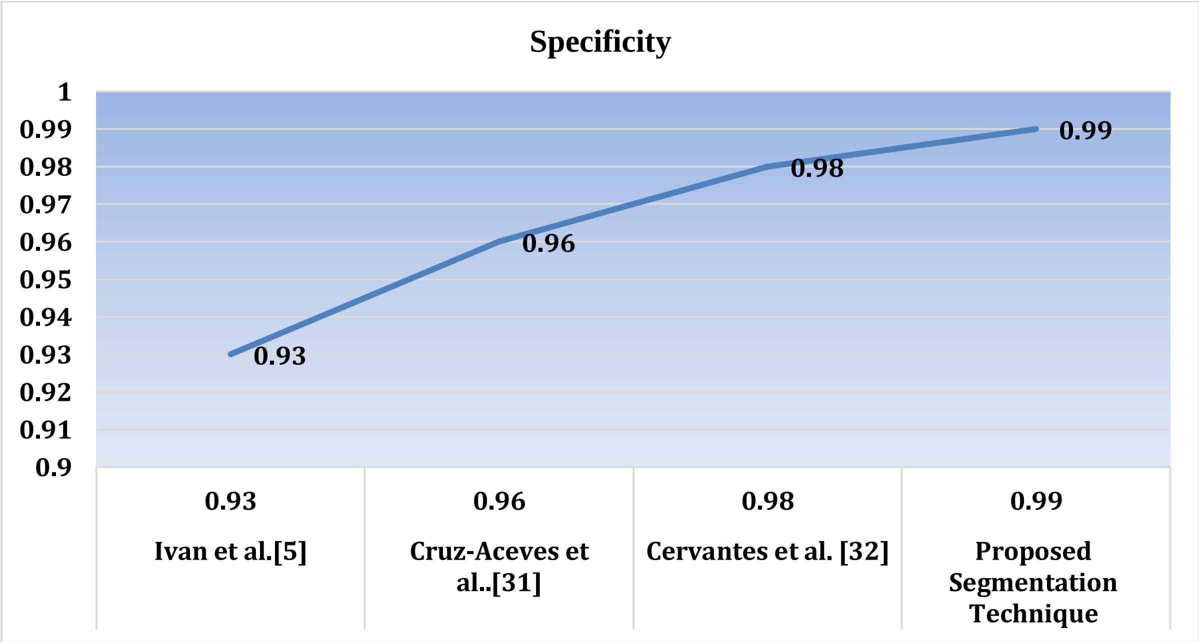


Fig. 6 Line plot comparison of specificity with the proposed hybrid segmentation method and state-of-the-method

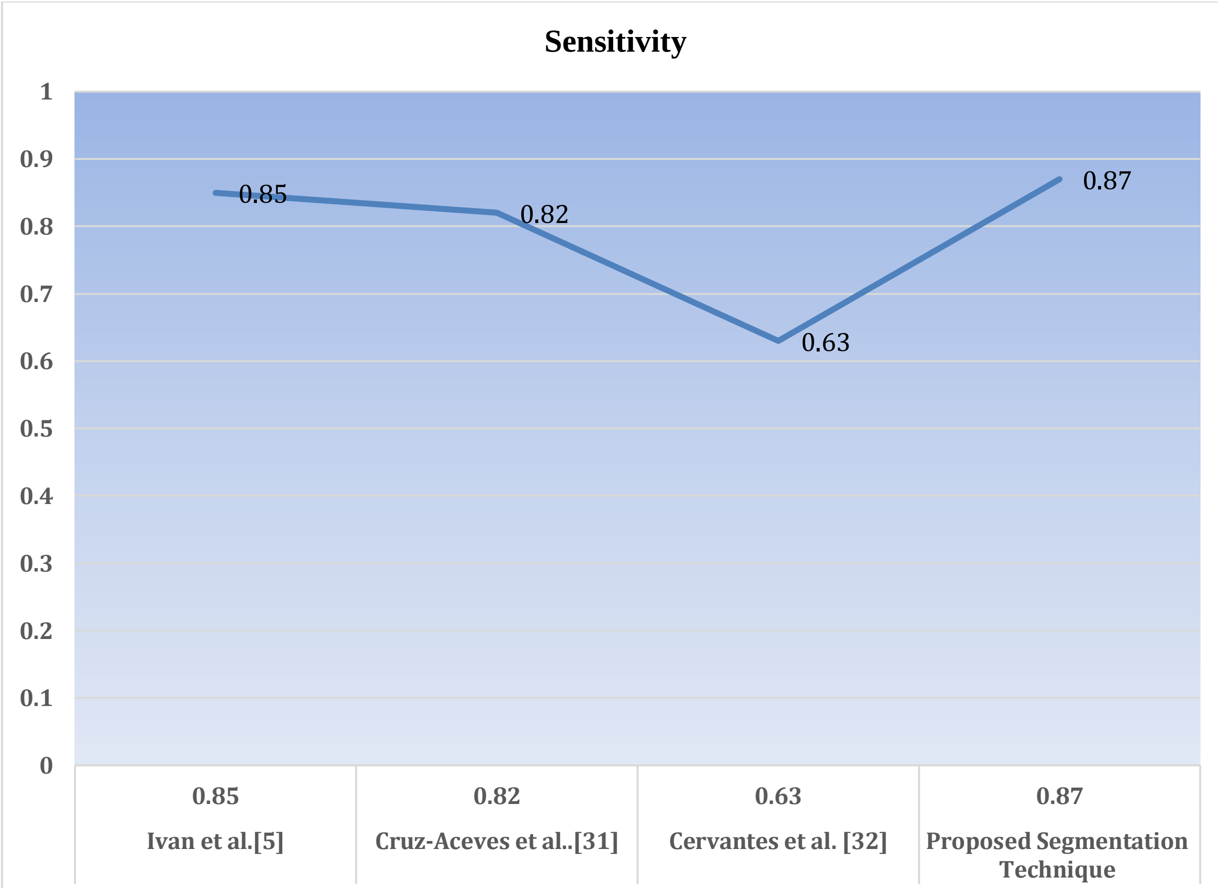


Fig. 7 Line plot comparison of Sensitivity with the proposed hybrid segmentation method and state-of-the-method

4.1 Performance Metrics

Jaccard Similarity Coefficient and Dice Similarity Coefficient have been used to assess the hybrid method's segmentation output quantitatively.

Dice Similarity Coefficient [33] is practiced to analyze the similarity between the ground truth image (manually segmented image) and the segmented image [34].

$$DC = \frac{2\times|M1\cap M2|}{|M1|+|M2|} \tag{9}$$

Where, $M1$ – Ground truth Image

$M2$ – Segmented Image

DC - Dice Similarity Coefficient

The values of DC are always between 0 and 1. If the values of DC are high, there is a great similarity between the segmented image and the ground truth and vice versa. Jaccard Similarity coefficient [35] is used to check the resemblance between any pair of vertices.

$$JS = \frac{|M1\cap M2|}{|M1|+|M2|+|M1\cap M2|} \tag{10}$$

where JS - Jaccard Similarity coefficient

Like DC[32], the JS values are also between 0 and 1. If the values of JS is high, it can be understood that the segmentation method is better than other methods.

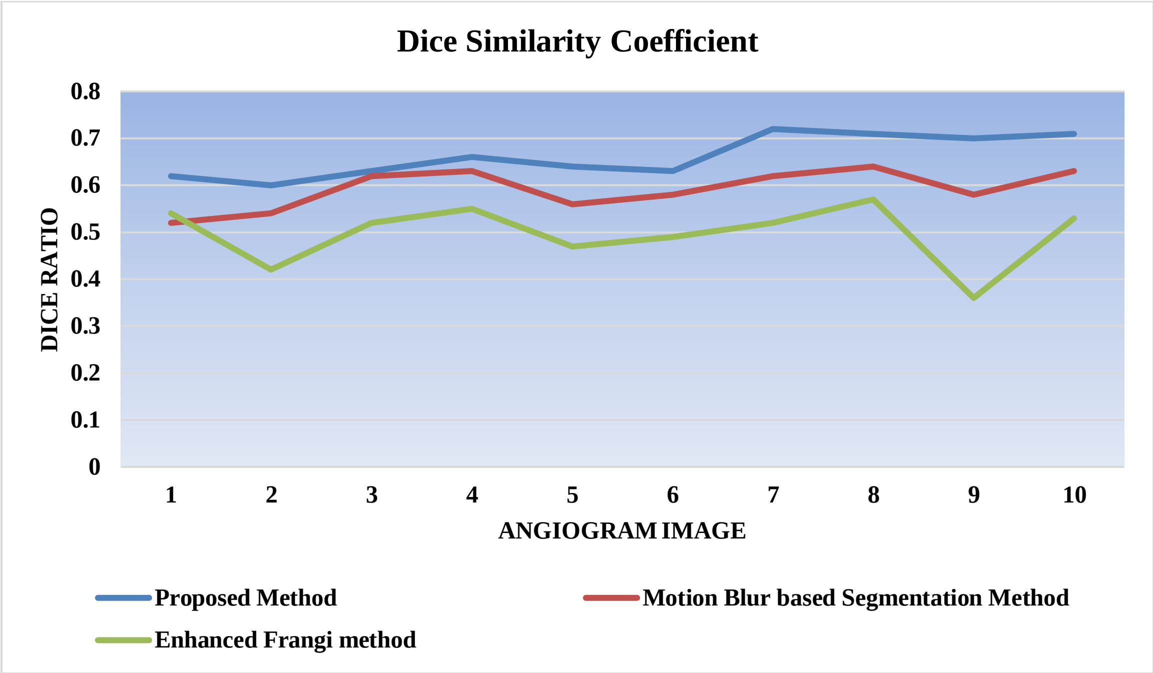


Fig. 8 Dice similarity coefficient ratio for the proposed hybrid segmentation method and existing segmentation methods

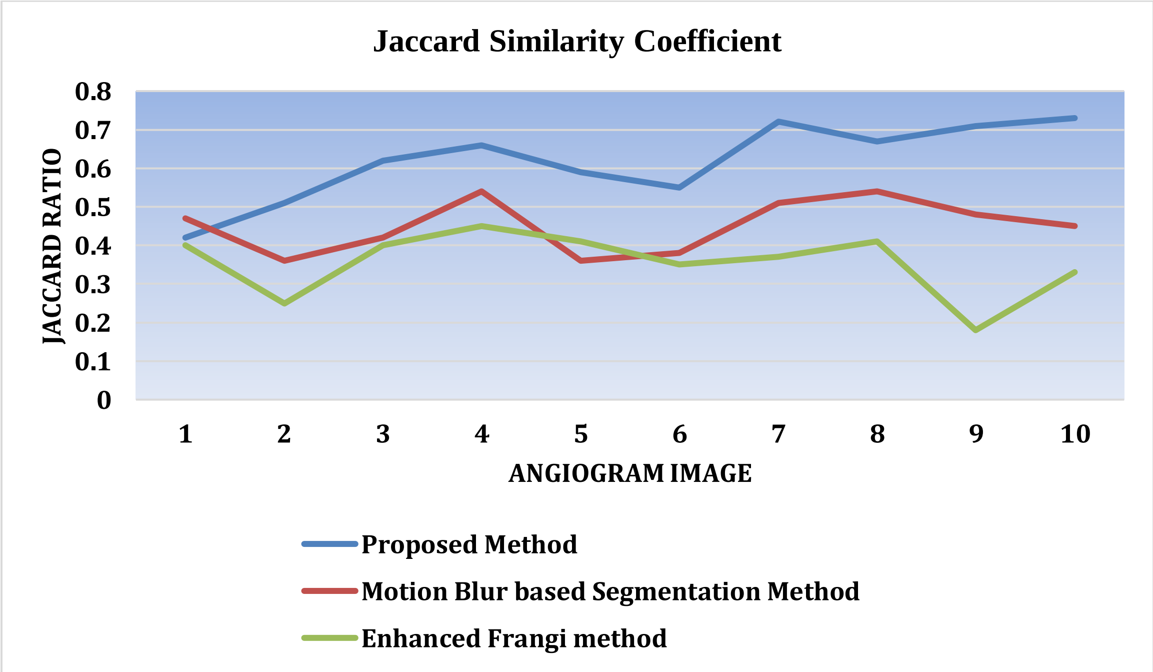


Fig. 9 Jaccard coefficient ratio for the proposed hybrid segmentation method and existing segmentation methods

Fig 8 shows the Dice similarity coefficient ratio for the proposed and existing hybrid segmentation techniques. The DC ratio of the proposed hybrid segmentation method has a higher value than the existing segmentation method. Fig 9 shows the Jaccard similarity coefficient (JC) ratio for the proposed hybrid segmentation technique and the existing techniques. Utmost of the Jaccard values obtained for the proposed hybrid segmentation method is higher when compared to the existing segmentation method. From the experimental results, it is understood that the proposed hybrid segmentation method for extraction of the coronary artery region performs better when related to the other existing techniques.

5. Conclusion

Heart disease is becoming more common in middle-aged people in the current era. One of the significant causes of cardiac disease is the blockage of the heart's blood vessels by plaque/fat. Most medical and technological professionals are working on identifying or predicting heart diseases. This research work focuses on segmenting coronary angiogram images for blockage detection. The dataset has been collected with due consent from the medical ethical committee. Once the dataset was acquired, the images were processed and segmented. The entire dataset was divided into training, testing, and validation sets. The keyframes were extracted using the proposed extraction method. Then, the Enhanced Frangi method was considered for extracting linear curve features. The motion blur method was used to segment and identify the region of interest. Finally, both the methods were hybridized to get the optimum results, which proved to be the best when related to other state-of-the-art segmentation methods proposed by researchers. The proposed model has a pixel accuracy of 95.75 for the segmented artery region. The method was also compared with ground truth values using the Jaccard Similarity Coefficient and Dice Similarity Coefficient. As part of future enhancements, the proposed method can be improved by including more features and implementing different segmentation methods.

References

[1] E. Badila, L. Calmac, D. Zamfir, D. Penes, E. Weiss, and V. Bataila, "The Cardiovascular System and the Coronary Circulation," Springer, Cham, 2017.

[2] R. J. Bache, "Coronary Artery Disease: Regulation of Coronary Blood Flow," in Coronary Artery Disease, Springer, London, 2015, pp. 57–67.

[3] D. R. Holmes and D. O. Williams, "Catheter-based treatment of coronary artery disease: past, present, and future.," Circ. Cardiovasc. Interv., vol. 1, no. 1, pp. 60–73, 2008, doi: 10.1161/CIRCINTERVENTIONS.108.783134.

[4] D. B. Mark et al., "ACCF/ACR/AHA/NASCI/SAIP/SCAI/SCCT 2010 Expert Consensus Document on Coronary Computed Tomographic Angiography. A Report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents," J. Am. Coll. Cardiol., vol. 55, no. 23, pp. 2663–2699, 2010, doi: 10.1016/j.jacc.2009.11.013.

[5] I. Cruz-Aceves, F. Oloumi, R. M. Rangayyan, J. G. Aviña-Cervantes, and A. Hernandez-Aguirre, "Automatic segmentation of coronary arteries using Gabor filters and thresholding based on multiobjective optimization," Biomed. Signal Process. Control, vol. 25, pp. 76–85, 2016, doi: 10.1016/j.bspc.2015.11.001.

[6] R. Surendiran, M. Thangamani, C. Narmatha, M. Iswarya, "Effective Autism Spectrum Disorder Prediction to Improve the Clinical Traits using Machine Learning Techniques", International Journal of Engineering Trends and Technology, vol. 70, no. 4, pp.343-359, 2022. https://doi.org/10.14445/22315381/IJETT-V70I4P230.

[7] Y. Tian, Y. Pan, F. Duan, S. Zhao, Q. Wang, and W. Wang, "Automated Segmentation of Coronary Arteries Based on Statistical Region Growing and Heuristic Decision Method," Biomed Res. Int., vol. 2016, 2016, doi: 10.1155/2016/3530251.

[8] S. Mabrouk, C. Oueslati, and F. Ghorbel, "Multiscale Graph Cuts Based Method for Coronary Artery Segmentation in Angiograms," IRBM, vol. 38, no. 3, pp. 167–175, 2017, doi: 10.1016/j.irbm.2017.04.004.

[9] F. Cervantes-Sanchez, I. Cruz-Aceves, A. Hernandez-Aguirre, S. Solorio-Meza, T. Cordova-Fraga, and J. Gabriel Aviña-Cervantes, "Coronary Artery Segmentation in X-ray Angiogram using Gabor filters and Differential Evolution," Appl. Radiat. Isot., vol. 138, pp. 18–24, 2018, doi: https://doi.org/10.1016/j.apradiso.2017.08.007.

[10] K. Jo, J. Kweon, Y. H. Kim, and J. Choi, "Segmentation of the Main Vessel of the Left Anterior Descending Artery Using Selective Feature Mapping in Coronary Angiography," IEEE Access, vol. 7, pp. 919–930, 2019, doi: 10.1109/ACCESS.2018.2886009.

[11] M. EminTenekeci, H. Pehlivan, and Y. Kaya, "Improving performance of coronary artery segmentation using calculated vessel location from the angiogram."

[12] A. Carballal et al., "Automatic multiscale vascular image segmentation algorithm for coronary angiography," Biomed. Signal Process. Control, vol. 46, pp. 1–9, 2018, doi: 10.1016/j.bspc.2018.06.007.

[13] J. L. Lai and Y. Yi, "Key frame extraction based on visual attention model," J. Vis. Commun. Image Represent., vol. 23, no. 1, pp. 114–125, 2012, doi: 10.1016/j.jvcir.2011.08.005.
[14] M. K. Asha Paul, J. Kavitha, and P. A. Jansi Rani, "Keyframe Extraction Techniques: A Review," Recent Patents Comput. Sci., vol. 11, no. 1, pp. 3–16, doi: 10.2174/2213275911666180719111118.
[15] A. Jahagirdar and M. Nagmode, "Two level key frame extraction for action recognition using content based adaptive threshold," Int. J. Intell. Eng. Syst., vol. 12, no. 5, pp. 43–52, 2019, doi: 10.22266/ijies2019.1031.05.
[16] F. Ciompi, O. Pujol, S. Balocco, X. Carrillo, J. Mauri, and P. Radeva, "Automatic Key Frames Detection in Intravascular Ultrasound Sequences," MICCAI Work. …, no. 1, 2011.
[17] A. F. Frangi, W. J. Niessen, K. L. Vincken, and M. A. Viergever, “Multiscale vessel enhancement filtering,” Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 1496, no. February, pp. 130–137, 1998, doi: 10.1007/bfb0056195.
[18] P. T. H. Truc, M. A. U. Khan, Y. K. Lee, S. Lee, and T. S. Kim, "Vessel enhancement filter using directional filter bank," Comput. Vis. Image Underst., vol. 113, no. 1, pp. 101–112, 2009, doi: 10.1016/j.cviu.2008.07.009.
[19] R. Surendiran, K. Duraisamy, "An Approach in Semantic Web Information Retrieval," SSRG International Journal of Electronics and Communication Engineering, vol. 1, no. 1, pp.17-21, 2014. https://doi.org/10.14445/23488549/IJECE-V1I1P105.
[20] R. Moreno and Ö. Smedby, "Gradient-based enhancement of tubular structures in medical images," Med. Image Anal., vol. 26, no. 1, pp. 19–29, 2015, doi: 10.1016/j.media.2015.07.001.
[21] Z. Li, Y. Zhang, G. Liu, H. Shao, W. Li, and X. Tang, "A robust coronary artery identification and centerline extraction method in angiographies," Biomed. Signal Process. Control, vol. 16, pp. 1–8, 2015, doi: 10.1016/j.bspc.2014.09.015.
[22] F. Zhang, X. Zhang, X. Liu, K. Cao, H. Du, and Y. Cui, "Blood vessel enhancement for DSA images based on adaptive multiscale filtering," Optik (Stuttg)., vol. 125, no. 10, pp. 2383–2388, 2014, doi: 10.1016/j.ijleo.2013.10.111.
[23] M. E. Martinez-Perez, A. D. Hughes, S. A. Thom, A. A. Bharath, and K. H. Parker, "Segmentation of blood vessels from red-free and fluorescein retinal images," Med. Image Anal., vol. 11, no. 1, pp. 47–61, 2007, doi: 10.1016/j.media.2006.11.004.
[24] L. Gong, X. Du, C. Lin, K. Zhu, C. Liu, and W. Liang, "Automated High-Resolution Structure Analysis of Plant Root with a Morphological Image Filtering Algorithm," Math. Probl. Eng., vol. 2021, 2021, doi: 10.1155/2021/4021426.
[25] K. Chen, Q. Yin, X. Jia, and M. Lu, "Image Enhancement based Improved Multiscale Hessian Matrix for Coronary Angiography," Int. J. Comput. Appl., vol. 126, no. 10, pp. 1–4, 2015, doi: 10.5120/ijca2015906196.
[26] L. C. Rodrigues and M. Marengoni, "Segmentation of optic disc and blood vessels in retinal images using wavelets, mathematical morphology and Hessian-based multiscale filtering," Biomed. Signal Process. Control, vol. 36, pp. 39–49, 2017, doi: 10.1016/j.bspc.2017.03.014.
[27] B. Peng, Y. Wang, and X. Yang, "A multiscale morphological approach to local contrast enhancement for ultrasound images," Proc. - 2010 Int. Conf. Comput. Inf. Sci. ICCIS 2010, vol. 80, pp. 1142–1145, 2010, doi: 10.1109/ICCIS.2010.282.
[28] G. S. Tejaswi D. Prakash, Deepthi Rajashekar, "Comparison Of Algorithms For Segmentation Of Blood Vessels In Fundus Images," 2nd Int. Conf. Appl. Theor. Comput. Commun. Technol., pp. 114–118, 2016.
[29] E. Moghimirad, S. Hamid Rezatofighi, and H. Soltanian-Zadeh, “Retinal vessel segmentation using a multi-scale medialness function,” Comput. Biol. Med., vol. 42, no. 1, pp. 50–60, 2012, doi: 10.1016/j.compbiomed.2011.10.008.
[30] Cruz-Aceves, Ivan, et al. "A novel Gaussian matched filter based on entropy minimization for automatic segmentation of coronary angiograms." Computers & Electrical Engineering 53 (2016): 263-275.
[31] Cruz-Aceves, Ivan, Arturo Hernandez-Aguirre, and S. Ivvan Valdez. "On the performance of nature inspired algorithms for the automatic segmentation of coronary arteries using Gaussian matched filters." Applied Soft Computing 46 (2016): 665-676.
[32] Cervantes-Sanchez, Fernando, et al. "Automatic segmentation of coronary arteries in X-ray angiograms using multiscale analysis and artificial neural networks." Applied Sciences 9.24 (2019): 5507.
[33] B. Toptaş and D. Hanbay, "Retinal blood vessel segmentation using pixel-based feature vector," Biomed. Signal Process.
[34] Control, vol. 70, no. April, 2021, doi: 10.1016/j.bspc.2021.103053.
[35] G. Ma, J. Yang, and H. Zhao, "A coronary artery segmentation method based on region growing with variable sector search area," Technol. Heal. Care, vol. 28, no. S1, pp. S463–S472, 2020, doi: 10.3233/THC-209047.
[36] R. Surendiran, R. Aarthi, M. Thangamani, S. Sugavanam, R. Sarumathy, " A Systematic Review using Machine Learning Algorithms for Predicting Preterm Birth," International Journal of Engineering Trends and Technology, vol. 70, no. 5, pp.46-59, 2022. https://doi.org/10.14445/22315381/IJETT-V70I5P207.
[37] F. Cervantes-Sanchez et al., "Segmentation of Coronary Angiograms Using Gabor Filters and Boltzmann Univariate Marginal Distribution Algorithm," Comput. Intell. Neurosci., vol. 2016, 2016, doi: 10.1155/2016/2420962.

[38] F. Cervantes-Sanchez, I. Cruz-Aceves, A. Hernandez-Aguirre, F. Cervantes-Sanchez, and I. Cruz-Aceves, "Automatic detection of coronary artery stenosis in X-ray angiograms using Gaussian filters and genetic algorithms," vol. 020005, no. June 2016, doi: 10.1063/1.4954092.

[39] R. Surendiran, K.Alagarsamy, "Skin Detection Based Cryptography in Steganography (SDBCS)," International Journal of Computer Science and Information Technologies, vol. 1, no. 4, pp.221-225, 2010.

[40] N. H. H. Thanh, Dang NH, Dvoenko Sergey, V. B. Surya Prasath, "Blood Vessels Segmentation Method For Retinal Fundus Images Based On Adaptive Principal Curvature And Image Derivative," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. XLII, no. May, pp. 13–15, 2019.