A Modified ANFIS (MANFIS) Classification Technique to Identify the Heart Disease in Coronary Angiogram Images

[1]Dr.P.Rajesh Kumar, [2] K.Suresh Kumar, [3]Dr.V.Jai Ganesh, [4]Dr.S.Saraswathi, [5]Dr.S.Mohan

[125]Assistant Professor, Department of Electronics and Communication Engineering,
[3]Principal & Professor, Department of Mechanical Engineering,
[4]Associate Professor, Department of Electronics and Communication Engineering,
[125]Tagore Institute of Engineering and Technology, Deviyakuruchi, Salem, India – 636112
[45]Mahendra Engineering College, Mahendhriapuri, Namakal – 637503
[*]Corresponding Author: Dr.P.Rajesh Kumar.

Abstract:

Due to the increased prevalence of coronary heart disease, the mortality rate has risen dramatically in recent years. The primary component that brings out the important features from angiogram images to identify the heart disease is coronary vessel blockage segmentation. The innovative Neuro -Fuzzy System (NFS) has emerged as a dominant technique for dealing with a wide range of difficult research problems. Adaptive Neuro - Fuzzy Inference System (ANFIS) has a significant disadvantage in terms of computational complexities. Meta-heuristic algorithms have been used by many researchers to make improvements in ANFIS characteristics. Using the Modified Adaptive Neuro - Fuzzy Inference System (MANFIS) classifier, this paper proposes an automated method of segmenting blockages from coronary angiogram images. Preprocessing, feature extraction, and classification are all part of the proposed method. The vessels are enhanced using a preprocessing technique, and then features are extracted and fed into the MANFIS classifier. This classifier categorizes the given test coronary image as normal or unusual. If the proposed system classifies the test image as unusual, the blockage is detected and segmented. In detecting pixels in blocked blood vessels, the proposed MANFIS technique achieves better results in terms of sensitivity (99.97%), specificity (99.96%), and accuracy (99.98%). The proposed system performance is compared to traditional Support Vector Machine (SVM) and ANFIS methods.

Keywords: Coronary vessel, Feature extraction, Angiogram, Modified ANFIS (MANFIS) classifier, Preprocessing, Meta-heuristic algorithm.

1.Introduction

Every year, more people die from heart disease around the world. The primary causes of heart disease are smoking, obesity, high blood pressure, and blood vessel inflammation. Diabetic patients and chain smokers are more likely to develop coronary heart disease. Patient mortality is reduced when coronary heart disease is detected and diagnosed early. The blood vessels in the heart have been severely damaged as a result of heart abnormalities. The flow of blood within the blood vessels is disrupted as a result of this abnormality, resulting in vessel blockage. According to the World Health Organization (WHO), coronary heart disease affects one lakh and twenty thousand people worldwide each year.

Figure 1 depicts the coronary heart artery or vessels in normal and abnormal configurations. When the structure of the coronary vessels is abnormal, lipids are deposited inside, impeding blood flow. The MANFIS classifier is used to detect the blockage in coronary heart images in this paper. The main advantage of the MANFIS classifier is that it combines meta-heuristic Artificial Bee Colony (ABC) algorithm with ANFIS [1], which improves classification rate.

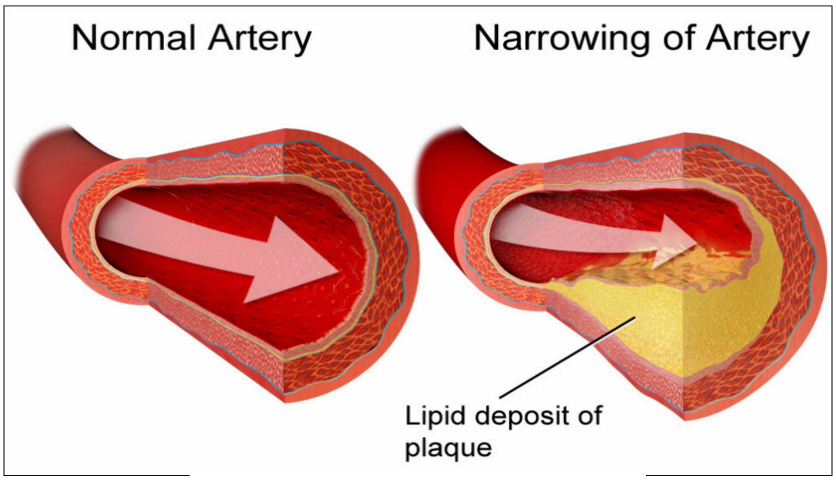


Figure 1 Basic Heart Artery Model

The following is how this paper is structured: Section 2 describes the standard methods for detecting coronary block in coronary heart images. Section 3 proposes a computer-assisted automated classification technology for detecting vessel blockage in coronary heart images, and Section 4 discusses the experimental results and their comparisons with conventional methods. Section 5 brings this paper to a close.

2 Literature Survey

Julien Ples To detect coronary heart disease, Wiharto *et al.,* [2] (2015) used a Support Vector Machine (SVM) classification technique. Using angiogram images, this study classified coronary heart disease as low, medium, high, or severe. The authors achieved a 90% recall rate, a precision of 82.143%, an F-measure of 86.793%, and an overall accuracy of 60%.

Hongzong *et al.,* [3] (2015) proposed a method for distinguishing Coronary Heart Disease from Non-coronary Heart Disease patients. The accuracy of the prediction training set was 96.86%, and the accuracy of the prediction testing set was 78.18%. The authors achieved a 92.67% cross validation prediction accuracy.

Using feed forward back propagation neural networks, Ebenezer Obaloluwa Olaniyi *et al.,* [4] (2015) created a framework for detecting and diagnosing heart disease. The authors' proposed algorithm received an 85% recognition rate.

Danilo Neglia *et al.,* [5] (2015) proposed an image processing-based algorithm for detecting coronary artery disease. Over a set of 475 cardio images, the authors achieved sensitivity of approximately 91% and specificity of approximately 92% for their proposed algorithm. Both myocardial perfusion imaging and topographic angiography were used to test the proposed algorithm.

For the detection of coronary vessels in angiogram images, Qing Cao *et al.,* [6] (2013) proposed a minimum path based region growing algorithm. The authors extracted features in order to detect vessels in coronary images using the orientated profile symmetry information method.

Julien Plessis*et al.,* [7] (2016) used image fusion to detect Coronary Artery vessels in Coronary Angiography. To improve the interior region of the coronary heart images, two dissimilar modality images were merged using the pixel images.

This task, proposed by Liu *et al.,* (2020) [8], proposes significant differences between neural networks and images based on the high similarity between images of the heart in slices and other tissues to find the affected area.

Oliveira *et al.,* (2019) [9] use the images in the dataset as inputs to train and evaluate the classifier in a 6-layer neural network, which results in the identification of powerful artefacts.

According to P.Rajesh *et al.,* (2018) [10], this filter bank is calculated using a block-by-block method, and the energy level of each block is applied to the image. The highlighted image is created by replacing pixels with calculated energy values.ion technique.

The conventional methodologies reveal the following findings.

• There is no fully automated computer-assisted identification of blockage in coronary heart images.

• The blockage's accuracy level is not optimal for discovering coronary heart disease.

This paper proposes a computer-assisted automated identification of coronary heart disease by detecting the blockage in coronary heart images to overcome the drawbacks of most conventional methods.

3.Proposed Methodology

Figure 2 depicts the proposed MANFIS classification technique to detect the blockage in coronary heart images. To bring out the vessels in the coronary images, the noises are removed and the noise-free coronary image is enhanced using the Adaptive Histogram Equalization technique. Then, from the preprocessed coronary image, features such as GLCM and LBP are extracted. These extracted features are trained and categorized using the MANFIS classification technique to determine whether the coronary image is normal or unusual. Then, on the categorized coronary heart image, morphological operations are used to separate the blockage region in unusual blood vessels.

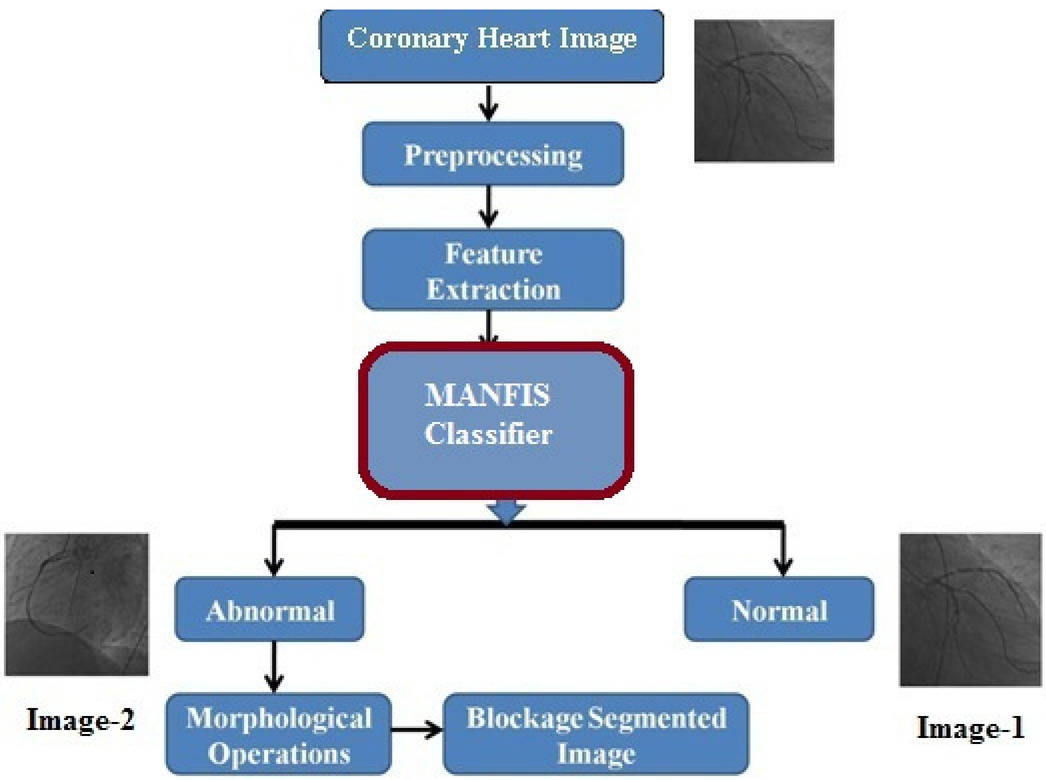


Figure 2 Proposed Coronary Block Detection System

3.1 Preprocessing

It is used to highlight pixel values in coronary heart images for accurate blockage detection. It is made up of 2 processes: noise reduction and enhancement. Noises in coronary heart images are removed using a Vector Median Filter (VMF) [11], and the noise-free image is enhanced using the adaptive histogram equalization technique. The following steps are used as the VMF procedure.

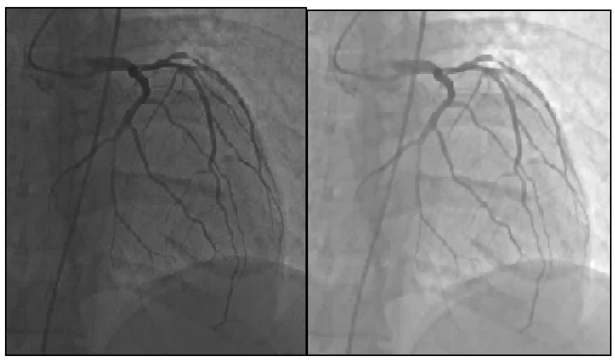
Step 1: Use the following equation to renew the centre pixel value based on the adjacent pixels: $x_c = \sum_{i=1}^{N} |x_c - x_i|$ (1)

where x_c is the centre pixel in the 3x3 sub window,

x_i is the adjacent pixels, and N is the number of pixels in the 3x3 sub window.

Step 2: After updating the centre pixel in the 3x3 sub window, the surrounding pixels are arranged according to their intensity values, and the median value is computed to replace the centre pixel in the 3x3 sub window. This process is repeated until there are no more pixels in the image.

Figure 3 depicts the preprocessed image of the coronary heart.



(a) (b)

Figure 3(a) Coronary Heart Image (b) Preprocessed Image

3.2 Feature Extraction

Extraction of features demonstrates the distinctiveness of the coronary heart image. These distinguishing features are used to bring out the coronary heart image as normal or unusual. Local Binary Pattern (LBP) and Gray Level Co-occurrence Matrix (GLCM) are used in this paper to represent the distinctiveness of the coronary heart image.

3.2.1 GLCM features

GLCM features represent the spatial distributions of pixels. The GLCM matrix is used to extract features such as energy, contrast, correlation, and homogeneity, which are then used to distinguish between normal and abnormal coronary heart images. The GLCM matrix can be built to any degree between 0 and 180. In this paper, the GLCM matrix is computed in a random manner at 45° (which achieves high classification accuracy after testing several trials). In the preprocessed coronary heart image, energy correlates with pixel randomness. Contrast represents the amount of grey level intensity differentiation. Correlation corresponds to the relationship between pixels. The homogeneity feature represents the cumulative distribution values. These characteristics are illustrated in the following equations as,

$$\text{Energy} = \sum p(i,j)^2 \tag{2}$$

$$\text{Contrast} = \sum\left(|i-j|^2 \times p(i,j)\right) \tag{3}$$

$$\text{Correlation} = \sum (i-\mu i)(j-\mu j)\frac{p(i,j)}{[\sigma i.\sigma j]} \tag{4}$$

$$\text{Homogeneity} = \sum_i \sum_j \frac{P(i,j)}{1+|i-j|} \tag{5}$$

Where i and 'j' represent the row and column of the GLCM matrix, respectively, and p (i,j) represents the corresponding values in the GLCM matrix. $'\sigma'$ Depicts the GLCM matrix's variance. The mean values of the GLCM matrix are μi and μj, respectively.

3.2.2 LBP features

LBP features can be used to represent texture information. These characteristics are computed for each pixel in the image. The preprocessed coronary heart image's centre pixel is compared to its surrounding pixels in the 3x3 sub window. The surrounding pixel is replaced by 1 if it is equal to or higher than the centre pixel, and by 0 if it is lower than the centre pixel.

The LBP feature is defined as,

$$LBP\ (x_c, y_c) = \sum_{p=0}^{P-1} s(g_p - g_c)2^P \tag{6}$$

where g_p stands for surrounding pixel, g_c stands for centre pixel, and 'p' stands for the number of surrounding pixels in a 3x3 sub window. Figure 4 depicts the extracted LBP feature image of the preprocessed coronary heart image.

Figure 4LBP Extracted Image

3.3 Classification

The classification is a method for categorizing coronary heart images as either block-free or blocked coronary heart image. For coronary heart image classification, conventional classifiers such as SVM [12] and ANFIS [13] are available. As the main limitations of SVM, multi-class classification is not possible, and it has high latency during the test phase of classification. The two complications of Neural Networks are logistic regression and increased computational burden. As a result, the MANFIS classifier is used in this paper to classify coronary heart images.

The main function of the MANFIS classifier is that it combines meta-heuristics Artificial Bee Colony (ABC) algorithm with ANFIS, which increases the classification rate. The feature vector was created by concatenating the GLCM and LBP features provided to the classifier and used to categorize the coronary heart image for blockage detection.

3.3.1 ANFIS Classifier

The extracted features from the preprocessed coronary heart image were fed into the ANFIS classifier input layer. Figure 5 represents the architecture of ANFIS.

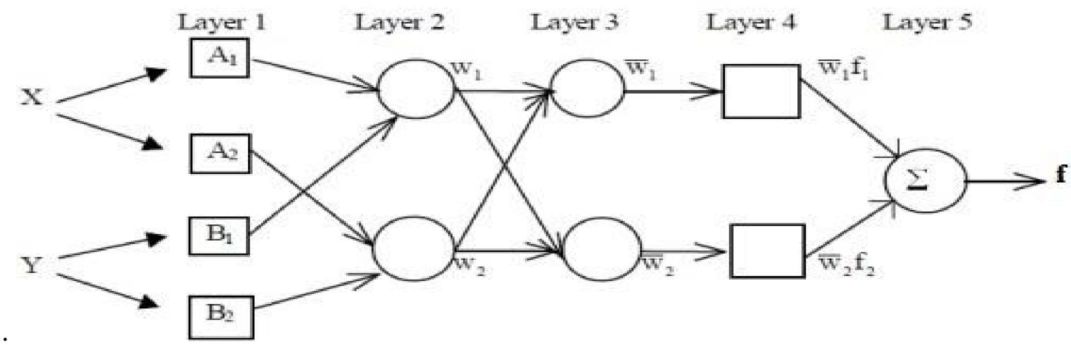


Figure 5 ANFIS Architecture

In the ANFIS architecture, based on a first-order Sugeno model two fuzzy IF-THEN rules are considered:

If X is A_1 and Y is B_1, then $f_1 = p_1X+q_1Y+r_1$ (7)

If X is A_2 and Y is B_2, then $f_2 = p_2X+q_2Y+r_2$ (8)

where X and Y are the inputs, A_i and B_i are the fuzzy sets, f_i, i = 1, 2 are the outputs of the fuzzy system and p_i , q_i and r_i were the design parameters that were determined during the training process. The ANFIS architecture implemented these two rules is shown in Figure 5, in which a circle indicated a fixed node whereas a square indicated an adaptive node. The output layer f produces binary value in which '0' represents block-free coronary heart image and '1' represents blocked coronary heart image.

3.3.2 Meta-heuristic Artificial Bee Colony (ABC) algorithm

Meta means "higher level" in meta-heuristic algorithms, and all meta-heuristic algorithms use some trade-off of local search and global exploration. Exploration and exploitation are the two main components of any meta-heuristic algorithm. Exploration refers to generating diverse solutions to explore the global search space, whereas exploitation refers to focusing on the search in a local region by utilizing information that a current good solution is found in this region. The two dimensions of ANFIS training are structure learning and parameter identification. The ABC (Artificial Bee Colony) optimization algorithm is used to train the parameters of the ANFIS model rather than the gradient-based learning mechanism.

The Artificial Bee Colony (ABC) algorithm is a swarm intelligence-based algorithm inspired by honey bee intelligence. Dervis Karaboga invented it in 2005 to solve optimization problems. The ABC algorithm has since been applied in fields such as data mining, image processing, and numerical problems.

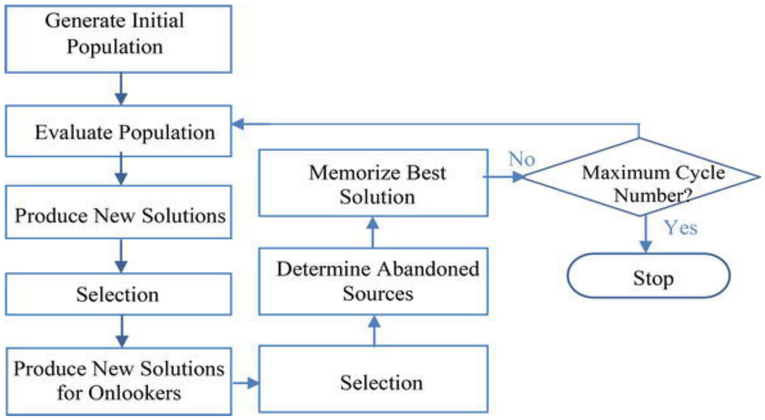
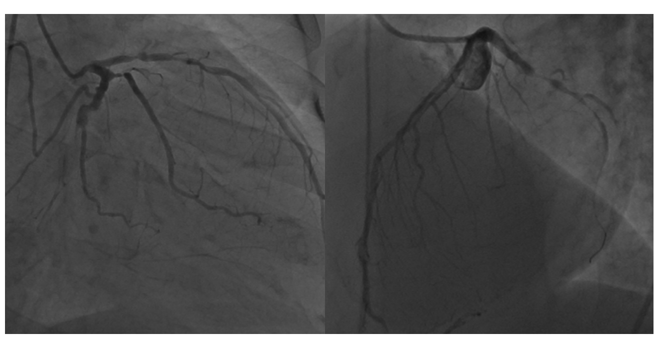


Figure 6 Meta-heuristic ABC Algorithms

As shown in Figure 6, the bees searching for food in ABC are divided into three groups: employed bees, onlooker bees, and scout bees. Employed bees used to hunt and gather information about the position and quality of food sources in the search space, while onlooker bees stayed in the hive and chose the food source based on the information provided by the employed bees. Scout bees attempt to arbitrarily replace abandoned employed bees in their search for new food sources [15]. The location of the food source is one possible solution to the optimization problem. The amount of nectar in a food source determined the problem's quality.

Figure 7 depicts the classification results. Figure 7(a) depicts the block-free coronary images, which show no vessel blockage. Figure 7(b) depicts coronary images with blockage, indicating vessel blockage. These images are from an open access dataset. Expert radiologists validate the classification results.

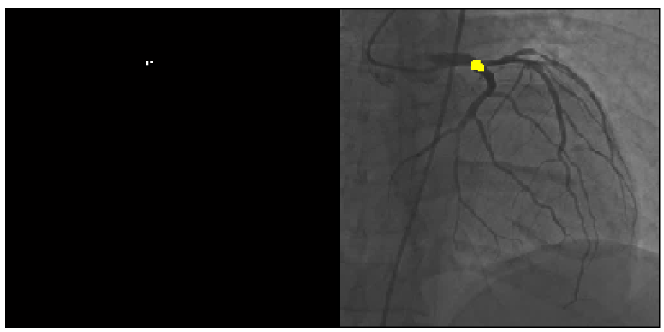


(a)

(b)

Figure 7 Classification results in (a) Block-free coronary images and (b) Coronary images containing block

Morphological operations are performed on the classified block that contains the coronary image. Dilation is followed by erosion in this process. To segment the block in a classified coronary heart image, the eroded image is subtracted from the dilated image. Figure 8(a) depicts this, while Figure 8(b) depicts the blockage overlaid coronary heart image 8(b).



(a) (b)

Figure 8 (a) Block detected image (b) Block segmented image

4. Results and Discussion

The proposed MANFIS classifier is used to detect blockages in coronary vessels and is applied to a set of coronary heart images collected using an open access dataset-Coronary Imaging. The proposed algorithm tested over 100 images, 75 of which are normal and 25 of which are abnormal. This proposed system is tested in MATLAB software, and the output values are obtained as a result. It also compares these results to the current method.

Table 1 GLCM features block-free and blocked coronary heart images

GLCM features	Block-Free Coronary Heart Images (Image-1)	Blocked Coronary Heart Images (Image-2)
Contrast	$16.67*10^3$	$17.29*10^3$
Correlation	$11.41*10^3$	$11.91*10^3$
Energy (In Joule)	$278.81*10^8$	$286.94*10^8$
Homogeneity	0.0348	0.3547

The extracted GLCM features for both block-free and blocked coronary heart images are shown in Table 1. According to Table 2, the GLCM features distinguish Block-free coronary heart images from Blocked coronary heart images. The values of the GLCM parameters for Block-free coronary heart images are lower than those for Blocked coronary heart images.

Table 2 Performance Comparisons of Proposed and Conventional Methodologies

Measurement	SVM	ANFIS	MANFIS
Sensitivity (%)	79.3	84.2	99.97
Specificity (%)	83.5	87.9	99.96
Accuracy (%)	87.4	91.6	99.98

Table 2 shows the proposed MANFIS and existing Space Vector Machine (SVM), Adaptive Neuro-Fuzzy Inference System (ANFIS) performance comparisons.

$$Sensitivity = \frac{TP}{TP+FN} \quad (9)$$

$$Specificity = \frac{TN}{TN+FP} \quad (10)$$

$$Accuracy = \frac{TP+TN}{TP+FN+TN+FP} \quad (11)$$

Where,

TPisa True Positive

TNisa True Negative

FPisa False positive

FNisa False Negative

Table 3 Error Value

Measurement	*Error Rate (%)*
SVM	12.6
ANFIS	8.4
MANFIS	0.025

Table 3 compares the error rates of the proposed MANFIS classifier method to those of the existing Support Vector Machine (SVM) and Adaptive Neuro-Fuzzy Inference System (ANFIS) methods.

5. Conclusion

This paper proposes computer-assisted automated identification of blockage in coronary heart images using the MANFIS classification technique. After preprocessing, the time domain coronary heart image is converted into a multi resolution image. The features extracted from this multi-resolution image are then trained and categorized using the MANFIS classification technique to detect the coronary heart image with blockage. For blockage vessel pixel detection, the proposed method achieves 99.97% sensitivity, 99.96% specificity, 99.98% accuracy and anerrorrate of 0.025%.In the future, the image enhancement approach could be extended to investigate the de-noising of any other highly corrupted and blurred coronary images.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

6.References

[1] https://www.intechopen.com/chapters/60337

[2] Wiharto, Hari Kusnanto, Herianto. (2015) ‘Performance Analysis of Multiclass Support Vector Machine Classificatiofor Diagnosis of Coronary Heart Diseases’, *International Journal on Computational Science & Applications,* Vol. 5, No. 5, pp. 27–37.

[3] Hongzong, S., Tao, W., Xiaojun, Y., Huanxiang, L., Zhide, H., Mancang, L., & BoTao, F. (2015) ‘Support Vector Machines Classification for Discriminating Coronary Heart Disease Patients from Non-coronary Heart Disease’,*West Indian Medical Journal,* Vol. 56, No. 5, pp. 451–457.

[4] Ebenezer Obaloluwa Olaniyi, & Oyebade Kayode Oyedotun. (2015) ‘Heart Diseases Diagnosis Using Neural Networks Arbitration’, *International Journal of Intelligent Systems and Applications,* Vol. 12, pp. 75-82.

[5] Danilo Neglia, Daniele Rovai, Chiara Caselli, Mikko Pietila. (2015) ‘Detection of Significant Coronary Artery Disease by Noninvasive Anatomical and Functional Imaging’,*Cardiovascular Imaging,* Vol. 8, No. 3,pp. 1–10.

[6] Qing Cao, Yang Chen, Guanyu Yang, Christine Toumoulin, Huazhong Shu, Limin Luo. (2013) ‘Coronary vessel extraction method using an improved minimum path based region growing’, *6th International Conference on Biomedical Engineering and Informatics,* pp. 127–131.

[7] Julien Plessis, Karine Warin Fresse, Zachary Cahouch, Thibaut Manigold. (2016) ‘Value of Image Fusion in Coronary Angiography for the Detection of Coronary Artery Bypass Grafts’,*Journal of the American Heart Association,*Vol.5, No. 6, pp. 245–256.

[8] H. Liu, W. Chu and H. Wang, (2020)“Automatic segmentation algorithm of ultrasound heart image based on convolutional neural network and image saliency”, *In IEEE Access*, vol. 8, pp. 104445-104457.

[9] A.T. Oliveira and E. G. O. Nobrega, (2019) “A novel arrhythmia classification method based on convolutional neural networks interpretation of electrocardiogram images”, *IEEE International Conference on Industrial Technology (ICIT)*, pp. 841-846.

[10] P.Rajesh Kumarand K.Murugesan, (2018) “Computer-aided segmentation of blockages in coronary heart images using canfis classifier”, *Wireless Personal Communications*, vol.*103,no.*2, pp.1341-1352.

[11] Yi Zhang, Dasong Li, Ka Lung Law, Xiaogang Wang, Hongwei Qin and Hongsheng Li, (2022) “Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)”, pp. 2098-210.

[12] Redrowthu, VijayaGajavelly, KovidNikath, A. Vasavi, R.Anumasula and Rakshith, (2022) “Heart disease prediction using decision tree and SVM”.

[13] Feng, Jindong, Wang QianLi and Na. (2010) “An intelligent system for heart disease prediction using adaptive Neuro-fuzzy inference systems and genetic algorithm”, *Journal of Physics: Conference Series*.

[14] https://www.healthcare.siemens.com/clinical-specialities/ cardiovascular/clinical-expert/coronary-imaging

[15] Uddin J. Optimization of ANFIS using artificial bee colony algorithm for classification of Malaysian SMEs. In: Recent Advances on Soft Computing and Data Mining: The Second International Conference on Soft Computing and Data Mining (SCDM-2016) Proceedings; August 18-20, 2016; Bandung, Indonesia: Springer International Publishing; 2017. ISSN 2194-5357.