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CAD-CDN: Coronary Artery Disease Prediction Using Convolutional Neural Network with Modified Densenet

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Abstract— Atherosclerosis is a synonym for coronary artery disease (CAD), a non-communicable cardiovascular disease. Coronary artery disease, cancer, and tumour illness pose significant human risks. Predicting coronary artery disease (CAD) is a difficult and time-consuming task in the medical field. Early prediction is a virtuoso skill in the medical area, particularly in the cardiovascular sector. Prior research on developing early prediction models provided a grasp of modern strategies for detecting variance in medical imaging. Cardiovascular disease prevention may be accomplished with a diet plan established by the concerned physician after early diagnosis. We proposed a CAD-CDN framework for coronary artery disease prediction using a Convolutional neural network (CNN) with modified densenet. The datasets are collected from the Kaggle repository, and the data normalization has been done with Affinity propagation with an adaptive damping factor (APADF). The best features are selected using ACO with SA as the Hybrid method. Finally, the classification was done with CNN with modified Densenet. The experimental result has been done with various existing algorithms and proposed one. And the results have shown performance indicators including accuracy, precision, sensitivity, specificity, and measure value.

Keywords- ACO-SA, APADF, CNN, Coronary Artery Disease, M-Densenet

I. INTRODUCTION

Heart disease is a category that includes coronary artery disease [1]. The World Health Organization (WHO) reports that heart disease accounts for 31% of all NCDs. Reduced oxygen-rich blood flow to the artery branches is a consequence of atherosclerosis, which occurs when lipids, plaques, and calcification build up inside the arterial wall [2-8]. In addition, ruptured plaques and calcification can constrict the patient's small arteries, leading to angina pectoris and myocardial infarction. We use a deep learning approach to investigate IVUS images for calcification in this study [9-17].

The social, economic, and medical repercussions of cardiovascular disease (CVD) are substantial, making it the leading cause of death in Western countries [18-22]. Atherosclerosis is the most common form of cardiovascular disease, and it is characterized by a local phenotype that is affected by systemic factors [23-26]. Hypertension and diabetes are two examples of systemic variables and comorbid conditions that may hasten the development of atherosclerosis. Hemodynamic factors, such as reduced ant colony optimization, contribute to the local symptoms of atherosclerosis. Gene expression, endothelial permeability, and inflammation are just some of the vascular physiologic processes shown to be altered by low ACO [27]. Recent years have seen the application of computational modelling in the study of atherosclerosis. Blood flow calculations and the correlation between low sugar and plaque development have been the primary focus of most investigations [28]. One major limitation of most of these efforts is the lack of a comprehensive study or clinical trial that combines information from all of these domains throughout two time periods to evaluate the development of atherosclerosis [29]. Detecting and diagnosing cardiac disease in individuals at an early stage may be difficult, but computer-aided procedures have been developed [30, 31]. To evaluate clinical data, interpret it, and offer diagnosis for medical disorders, machine learning is increasingly used as part of computer-aided detection procedures in medical facilities. Therefore, we put out a CAD-CDN architecture for foreseeing CAD.

The main contributions of this paper are as follows

- The dataset preprocessing has Affinity propagation with an adaptive damping factor (APADF).
- The best features are selected using ACO with SA as the Hybrid method.
- The disease classification was done with CNN with modified Densenet.

The remainder of the manuscript is structured as follows: Section II discussed related works for CAD prediction. The proposed CAD-CDN framework discussed in section III encompasses dataset description, preprocessing, feature selection and classification. Section IV contains experimental analysis, which details the

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parameters used to test the presence of the algorithm. Finally, section V discussed a conclusion and future scope.

II. BACKGROUND STUDY

D. Jamthikar et al. [2] the authors' proposed machine learning (ML) algorithm for predicting CAD and ACS. Both the XGBoost and RF algorithms implemented within the context of homogeneous ensemble methods showed improved endpoint prediction abilities for CAD and ACS. D. Zhang et al. [4] Images from X-ray angiography (XRA) may be used to estimate coronary artery stenosis directly. This author's HEAL model takes advantage of the complementary information regarding stenosis in two successive XRA images. H. Aakkara et al. [8] The predictive efficacy of seven different machine learning models for stenosis classification were compared in this study. M. Abdar et al. [16] Clinical decision support systems are becoming more important in modern healthcare. Improve the accuracy of statistical models used in CDSSs, which poses significant challenges for clinical researchers, patients, and clinicians. Coronary artery disease (CAD) is a leading global killer, which attracts the attention of a large scientific community. This case saw the use of the Nested Ensemble (NE) technique. N. Bhatti and S. I. A. Shah [23] These studies were conducted following certain guiding principles and simplifications, representing an advance over previous efforts. First, it has been demonstrated that cardiac exercise significantly affects coronary vertebrae; however, this study was not included. O. Mazumder et al. [25] Here, the author presents a new method for synthesizing PPG data by simulating electrophysiology and hemodynamic functions using a physical model of the heart system. S. K. K. L, N. K. G and M. J. A [29]

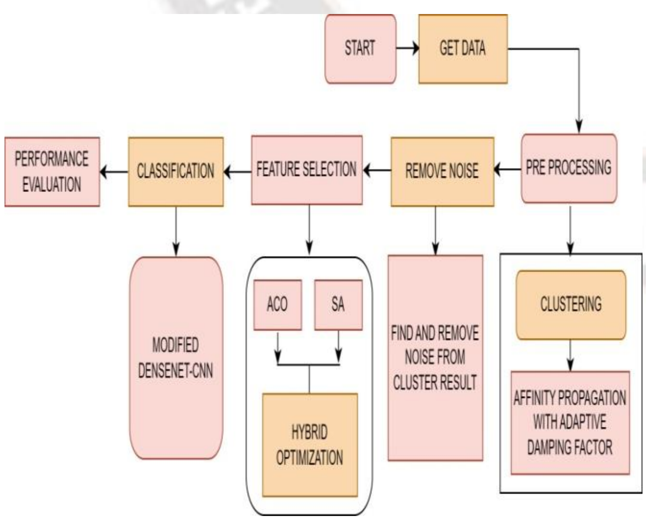

Figure 1: CAD-CDN framework

According to WHO statistics, cardiovascular disease is the leading cause of death worldwide, especially in less developed nations. It was crucial to anticipate the emergence of disorder to triumph over these obstacles.

2.1 Problem Definition

Angiography is the gold standard for diagnosing CAD now. However, the invasiveness of the procedure has the potential to put patients' lives in danger. Death rates between 0.1% and 0.14%, MI rates between 0.06% and 0.07%, stroke rates between 0.07% and 0.14%, reactions to contrast materials at 0.23%, and local vascular issues at 2% have all been attributed to angiography. Machine learning and deep learning algorithms have used the current prediction approach, although its accuracy is low. Therefore, we put out a CAD-CDN architecture for foreseeing CAD.

III. MATERIALS AND METHODS

Data Mining (DM) has been used to diagnose cardiac problems in recent decades. However, they're limited by things like inconsistent information, noise, missing data, outliers, high dimensionality, and imbalanced data. In order to improve the accuracy of DM-based prediction systems for HD, data preparation (DP) techniques were used. The Adaptive Damping-based affinity Propagation Clustering technique is utilized in this study to reduce noise and special features by using ACO with the SA algorithm. Finally, the classification is done with CNN-M-densenet.

A. Dataset collection

The dataset has been collected from https://www.kaggle.com/ronitf/heart-disease-uci link with 14 parameters, and 300 records are contained.

B. Normalization using Affinity propagation clustering algorithm

In Affinity Propagation, you may omit the cluster size parameter. Each data point broadcasts to every other data point a signal indicating the point's relative desirability to the receivers. Based on the appeal of messages received from all other senders, senders are told when a target is available for affiliation, and each target responds. Senders reply to targets by sending messages informing them of changes in their updated relative attractiveness to that target when statements from all marks are available. The procedure of message transmission is repeated until an agreement is reached.

Uses four matrices to cluster, i.e.,
1. Similarity matrix,
Minimum possible similarity
Maximum possible similarity

Median Possible similarity.
2. Availability matrix,
3. Responsibility matrix,
4. Criterion matrix
3.2.1 Process:
Step 1: Examine the data for patterns.
Step 2: Put in a zero for availability to start.

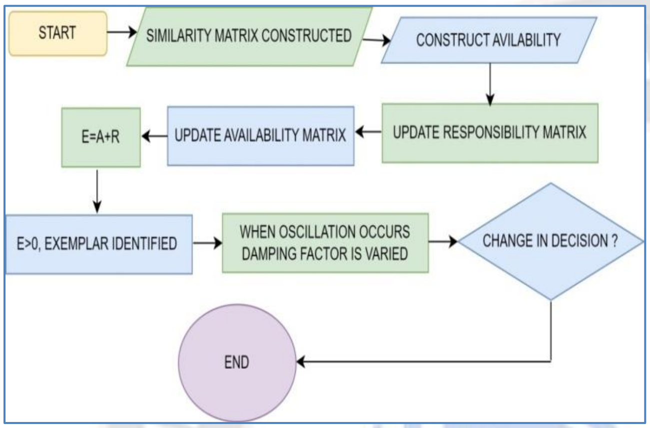

Figure 2: Noise Removal using APADF

a. Affinity Propagation Pseudo-Code:

Calculate the similarity matrix using the Median Possible similarity.
Dist(i , j)= -||xi-xj||²
Calculate Responsibility R(i,k)
R(i,k)=s(i,k)-max(a(i,k)-s(i,k))
s(i,k)->Similarity Matrix
a(i,k)-> Availability Matrix
Add the damping factor.
Rf= lam*Rold
R=(1-lam)*R+ Rf
Lam-> Damping Factor (lam=0.5)
R ->Rt+1(i,k)
Rold ->Rt(i,k)
Calculate the Availability
A (i, k) =min {0, r(k, k)+ ∑ max(0,r(i, k)}
Add the damping factor for accessibility
A=(1-lam)*A+lam*Aold
Lam-> Damping Factor (lam=0.5)
A ->Rt+1(i,k)
Aold -> Rt(i,k)
Calculate exemplar
E=(Diag(A)+Diag(R))>0
A->Availability
R->Responsibility
From step 2 to step 6 process continues to reach the maximum iteration.
Calculate the convergence from the exemplar

Step 3: Refresh the availability and duty information
Step 4: Add in roles and availability to get some examples for data point I.
Step 5: If Exemplars didn't modify for a flat quantity of iterations, go to step (6). Else, go to Step (1)
Step 6: Allocate the information points to Exemplars based on utmost similarity to discover clusters Identify the clusters

AP is a novel and effective method of example learning. It is a quick clustering technique, particularly useful when dealing with large clusters, and it has many benefits, including speed, universal application, and high performance. When oscillations arise, AP is unable to eradicate them automatically. An adjustable damping factor is developed to reduce changes and enhance clustering performance to meet this need.

C. HYBRID FEATURE SELECTION

a. Ant colony optimization (ACO):

ACO is an approximate solution discovery method for hard optimization problems using a population-based metaheuristic. When solving an optimization issue, Automatic Coordinated Optimization (ACO) deploys a colony of virtual workers, sometimes known as "artificial ants," to find the best possible outcome. Before we can use ACO, we need to reframe the optimization issue as finding the best path in a weighted graph. By repeatedly traversing the network, the artificial ants (henceforth ants) build solutions. Pheromone models are a set of parameters associated with graph components (nodes or edges) whose values are altered in real time by ants, and they are used to produce solutions in a biased and stochastic fashion.

b. Simulated Annealing:

The global optimum of a function may be approached using the probabilistic approach of simulated annealing (SA). To tackle global optimization in a vast search space, many people turn to metaheuristics. In the process of simulated annealing, this delayed cooling is utilized to lower the probability of accepting non-optimal solutions. If the solutions are inadequate, we may have to widen our search for the greatest global solution. How simulated annealing techniques function will be briefly discussed here. The temperature gradually decreases from a non-negative starting point to zero. At each iteration, the algorithm selects a solution that is somewhat near to the current one, evaluates its quality, and then transitions to that solution based on the probability of selecting better or worse solutions, which stay 1 (or positive) and fall towards zero, respectively, as a function of temperature.

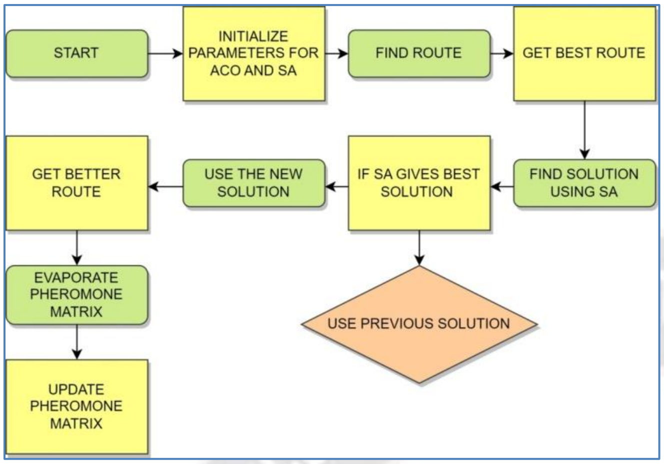

Figure 3: Hybrid Feature Selection

c. ACO with SA

First, k ants are generated and placed arbitrarily on the graph as part of the overall ACO feature selection process.
Another option is to have as many ants as there are features in the data, with each starting to build its path at a different quality.
Third, beginning at these points, they randomly walk along the edges until a stopping criterion is met, returning to their original starting points and finding the optimal path.

And new solution is found by using Simulated Annealing, and the process of Simulated annealing is described as Simulated annealing (SA) is an optimization method based on the similarity between the physical cooling process of a liquid and typical combination optimization problems. The implementation steps of the SA algorithm are as follows:
Step 1. Initialization:
Set a high initial temperature
Create an initial solution
Set iteration times for each temperature
Step 2. Choose a neighbour S2 of the current state randomly as a new potential solution, and calculate the fitness
Step 4. Accept S2 as the new current solution. Terminate the procedure when the predefined stopping criterion is met, and output the current solution as the best-so-far solution
If SA gives the best solution, take it as a new solution. Others wise take the previous solution as the best solution for an as resultant subset
Following this, we collect the resulting subsets and evaluate them. After a predetermined number of iterations of the algorithm or when the best subset of features has been found, the procedure ends, and the subgroup is printed.

7. If neither condition is met, the pheromone is updated, a new group of ants is created, and the process is repeated.

D. CNN WITH MODIFIED DENSENET CLASSIFICATION

Multiple convolutional layers are a staple of standard feed-forward neural networks. The term "densely connected convolutional network" (or "DenseNet") is used to refer to a network architecture in which each layer has direct communication with the other layers. Connectivity between the various "L" levels is as follows: L(L+1)/2.

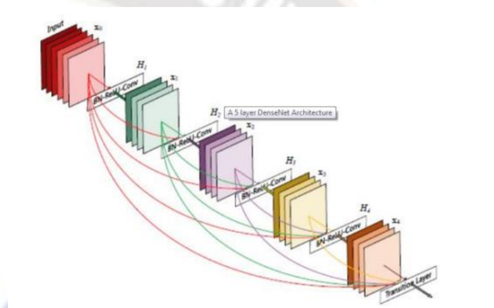

Figure 4: Modified Denset Architecture

a. DenseNet Architecture & Components

DenseNet has some different parts:
Connectivity
DenseBlocks
Growth Rate

b. Connectivity

All previous layers' feature maps are combined and sent into the current layer as inputs. DenseNets can reuse features because they don't need as many parameters as a conventional CNN and can eliminate unnecessary feature maps.

c. Dense Blocks

When the dimensions of the feature maps vary, it is impossible to use the concatenation operation. While CNNs are useful, they rely heavily on the down-sampling of layers to increase computation speeds by decreasing feature maps' dimensionality. Hl is a multi-stage function, as was seen above; each layer undergoes batch normalization (BN), a rectified linear unit (ReLU), and a convolution as part of the Hl iterative process.

d. Growth Rate

The characteristics represent the network as a whole. Each dense layer adds 'K' features to the initial global state, increasing the size of the feature map (existing features). Known as the network's growth rate, K controls how much new data is added to each successive layer. If k feature maps are produced by each H l function, where k0 is the number of channels in the input layer, those maps will be stored in the lth layer. As a result of their compact design, DenseNets can have fewer, more permeable layers than traditional network architectures.

E. CAD Prediction using Deep learning:

Modern businesses can benefit greatly from the evaluation and pattern extraction capabilities of data mining, which allows them to utilize their resources better. All relevant data was made available in a logical and easily accessible format. Using features derived from medical profiles like BP, age, sex, cholesterol, blood sugar, etc., a more advanced form of deep neural network (DNN) learning was developed to aid patients and healthcare providers and improve the accuracy and reliability of heart disease diagnosis and prognosis. Applying deep learning methods like regularization and dropout, the proposed DNN learning model achieves better results than a standard multilayer perceptron. Both a training-data-based classification model and a test-data-set diagnostic prediction model are part of the DNN learning model that was developed the feature maps produced in layers 0,...l −1. (·) l H is $x_l = H_l([x_0, x_1, \ldots, x_{l-1}])$. The compression and network performance may be optimized by changing the compression rate, block connection order, number of DenseBlock base layers, growth rate parameter K, and kind of pooling in the Transition Layer.

DenseNet
1 P0 ← Start with the proposed coding method for the population.;
2 t ← 0;
3 If the termination condition is not reached, iterate again：
4 Evaluate the Fitness of Pt ；
5 S ← To determine who will receive Pt's inheritance, use the championship method of selection；
6 Qt ← In the S population, individuals reproduce utilizing genetic operators；
7 Pt+1 ← Natural selection in the Pt-Qt environment；
8 t ← t+1
9 end
10 Pick the most accomplished member of the previous generation.

Convolutional Neural Networks
The convolution operation in CNN is only applied along one dimension, making the architecture shallow enough to be easily trained on regular CPUs or embedded development boards. CNN is very similar to traditional 2D CNN. Finding hierarchical features in the dataset that can be used for classification is a common application of the convolution function. The following formula can be used to determine the size of the features produced by a 1D CNN:

$$x = \frac{w+2p-f}{s} + 1 \text{ ------------- (1)}$$

Multiplying the input features' size by the output features' dimensions yields a new feature size, x. In convolutions, f denotes the size of the filter being used. Values added to the boundary before convolution is performed called padding, and the letter p means them.

IV. Results And Discussion

The suggested system was developed using MATLAB. According to the World Health Organization's (WHO) research, CAD is the greatest cause of mortality globally, particularly in underdeveloped countries. Anticipating the onset of the disease is crucial for overcoming these challenges. Methods that determine the proportion of true-positive and case-positive results are used to assess the number of parameters. The accuracy metric may use four features to determine the exact number of correct answers and their precise values.

These features are:
• True Positive: TP is the appropriate information for determining which category it belongs to..
• True Negative: TN is seen to be a discriminatory group due to its inaccurate information..
• False positives: FP is not valid information since it lacks an established classification. As a result, this is only one kind of mistake.
• False Negative: FN is useful information mistakenly assigned to a poor category. This is, however, a different kind of mistake.

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \text{ ------------ (2)}$$

The accuracy parameter represents the proportion of valid data determinations.

$$Precision \frac{TP}{TP+FP} \text{ ------------- (3)}$$

The recall settings define the number of usable records that are retrieved. The recall parameter determines the number of correct predictions by adding up the successes and subtracting the failures:

$$Recall \frac{TP}{TP+FN} \text{ --------- (4)}$$

The F-Measure approach strikes a nice balance between precision and credibility. These are the most effective methods for achieving that goal. Despite the method's intricacy, it's useful for making sound choices. The F-measure also provides numeric figures with which to assess the outcome.

$$f - Measure \frac{TP+TP}{TP+TN+FN+FP} \text{ --------- (5)}$$

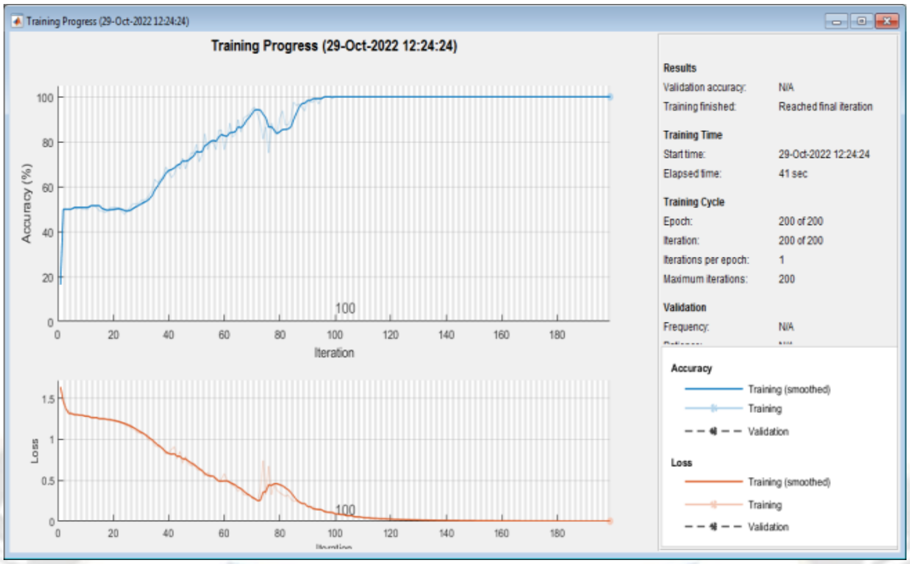

Figure 5: Training Process using CNN with Modified Densenet

The training and validation have been done with upto 200 epochs, and the training accuracy has achieved 99.9% in the 100th epoch. The training and validation loss has less than 0.2 on 100 periods onwards. So the model's optimum solution is represented in figure 5.

Table 1: Comparative analysis of existing algorithms with performance metrics

	KNN	KNN+FS	DEC TREE	DEC TREE + OS	RF	RF+FS	CNN (Proposed)
ACCURACY	82.5000	83.7500	97.8495	95.6989	85.0000	95.6989	98.5507
ERROR RATE	17.5000	16.2500	2.1505	4.3011	15.0000	2.1505	1.4493
SENSITIVITY	71.1667	72.5000	96.6667	94.3137	73	94.3137	98.5714
SPECIFICITY	94.0427	95.3803	99.5214	98.2222	95.3675	98.4035	99.3939
PRECISION	78.2413	82.6384	93.6667	98.4615	75.5731	97.5735	99.4595
FPR	5.9573	4.6197	0.4786	1.7778	4.6325	1.5965	0.6061
F1_SCORE	73.9267	75.2892	94.7569	96.2077	72.5790	95.8335	98.9853
MCC	69.3486	72.2274	94.4947	94.9453	69.6378	94.6067	98.5263
Kappa	45.3125	49.2188	93.2796	86.5591	53.1250	86.5591	95.4710

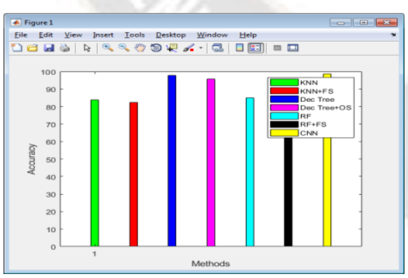

Figure 6: Accuracy comparison chart

The accuracy comparison has been made with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 6. In X-axis denotes methods, and Y-axis indicates accuracy in percentage.

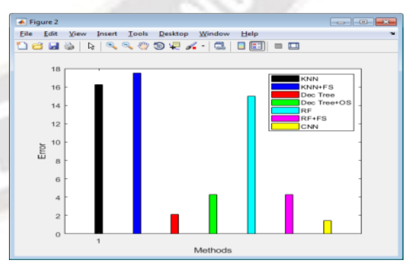

Figure 7: Error Comparison chart

The Error rate comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 7. In X-axis denotes methods, and Y-axis indicates an Error percentage.

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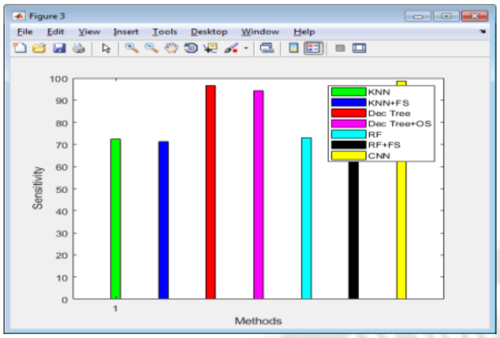

Figure 8: Sensitivity with various algorithms

The Sensitivity comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 8. In X-axis denotes methods, and Y-axis indicates sensitivity in percentage.

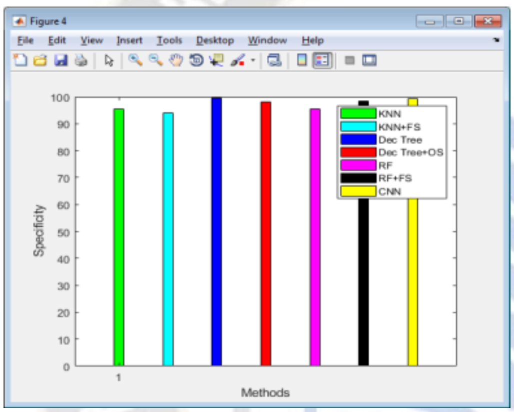

Figure 9: specificity with various algorithms

The Specificity comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 9. In X-axis denotes methods, and Y-axis indicates specificity in percentage.

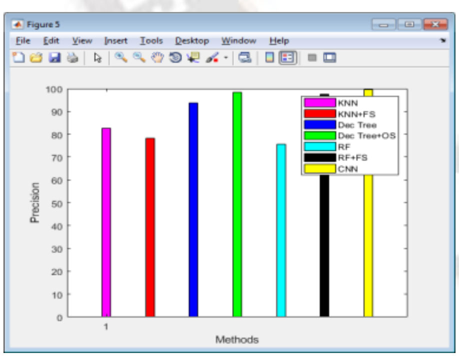

Figure 10: Precision comparison chart

The precision comparison done with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 10. In X-axis denotes methods, and Y-axis indicates precision in percentage.

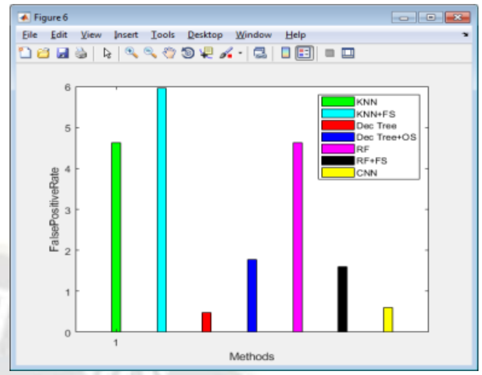

Figure 11: false positive rate comparison chart

The false positive rate comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 11. In X-axis denotes methods, and Y-axis indicates a false positive rate.

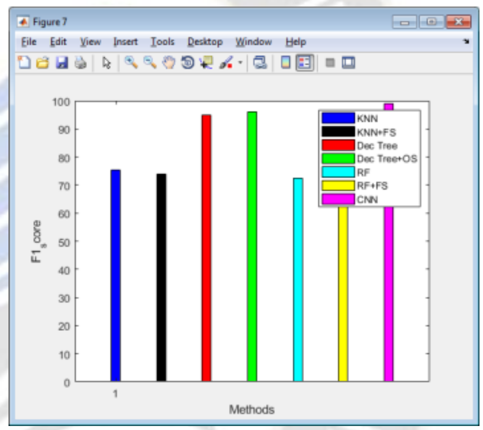

Figure 12: F1 Score Comparison chart

The F1 Score comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 12. In X-axis denotes methods, and Y-axis indicates F1-Score in percentage.

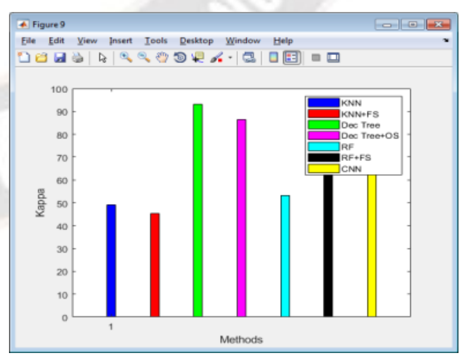

Figure 13: Kappa Score Comparison chart

The kappa comparison with KNN, KNN with FS, Decision tree, RF, RF+FS and CNN algorithm is shown in figure 13. In X-axis denotes methods, and Y-axis indicates Kappa in percentage.

V. CONCLUSION

We proposed a CAD-CDN framework for early prediction of CAD—this research presented with CNN trained with a modified densenet Network. Compared to other homogeneous ensemble algorithms, CNN with modified densenet and ACO algorithms demonstrated superior CAD prediction performance. Some hybrid algorithms, like Naïve Bayes with DT and RF, RGRD with C4.5, NB+MLB PART, NB with CFS, SVM + CHI Square; RF with PCA, RF with Hybrid SAACO have been shown to outperform other deep learning-based algorithms at predicting CAD by using CNN with M-Densenet. The dataset has normalized with APADF, and features are selected using hybrid optimization techniques. The experimental results have shown that the proposed method has achieved 98.5% accuracy. For future studies to implement Deep hybrid learning with mixed optimization techniques to achieve higher accuracy and medical recommendation to avoid heart disease problems.

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