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# CLASSIFICATION OF CORONARY ARTERY DISEASE USING HYBRID APPROACH

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**ABSTRACT**

Cardiovascular diseases (CVDs) are known globally to be among the major cause of sudden death, hence the prompt identification of CVDs could help reduce the casualties recorded via them. Diagnosis is a medical term used to describe the "process" involved that lead to the identification of a specific illness. When it comes to Coronary Artery Disease (CAD), however, this is achieved by following sophisticated and costly medical procedures in well-equipped hospitals and healthcare facilities. Furthermore, these procedures usually require only highly qualified medical experts to apply invasive methods. The number of patients who have access to this facility is limited. This research employs the use of Deep Neural Network (DNN) for the diagnosis of CAD for four (4) different datasets with Particle Swarm Optimization (PSO) assisted method for DNN. The aim of this research is to enhance the accuracy of diagnosing heart disease. Developed a conceptual framework to analyze CAD, also integrated PSO training algorithm to train DNN. Finally, evaluate and validate the performance of the proposed hybrid model with benchmark model. The research has shown that PSO is an effective evolutionary computing technique that improves the accuracy of classification. PSO selects the most optimum weight for DNN and increases the classification accuracy. The percentage improvement of the PSO hybridization to DNN are 8.8%, 11.4%, 3.3%, and 11.0% for Cleveland, Hungarian, Switzerland and ValongBeach respectively. The method put forward can improve patient diagnosis reliability and performance as it concerns CAD detection.

**Keywords:** Coronary Artery Disease, Classification, Diagnos**is,** Data mining, Medicine, Neural Network, Particle Swarm Optimization

## INTRODUCTION

Heart diseases such as Coronary artery disease (CAD), Atrial Fabrication, Myocarditis, hypertension, heart attack etc. are mostly referred to as silent killers (WHO, 2013) as they don't normally reveal themselves. The cause of death by various diseases among which include; stroke, respiratory infection, tuberculosis, diabetes, liver disease, diarrheal, heart disease, road injury which heart disease shows high death rate among others (Geneva, 2016). Measuring what number of people passes on every year and why they die is a standout amongst the most important means alongside gauging how diseases and injuries are influencing people for surveying the effectiveness of a nation's health system. (WHO, 2018).

Different methods have been applied to diagnose heart diseases, Decision trees (Nahar, 2013), Naive Bayes (Baati *et al.*, 2013), Simple Logistic (Prez, 2015), Neural classifiers (Singh, *et al.* 2014), Fuzzy classifiers (Srinivas *et al.*, 2014), etc. Some have speed benefits and can easily be applied to data sets, each with its own advantages and disadvantages. These methods cannot produce significant quality in classification in terms of accuracy. They have the following limitations: J48 is one of the well-known algorithms it create insignificant branches number which does not only reduce the usability of decision trees, but also the problem of overfitting. (Taneja, 2014). Simple logistic has convergence failures (Paul *et al.*, 2008). Naive Bayes is also known as a bad estimator, so the probability outputs are not reliable, it can only learn linear discriminant functions (Duda, 1973). The main limitation of Random forests is their complexity. They are much harder and time-consuming to construct (Gilles, 2006). Particle Swarm Optimization (PSO) is based on swarm intelligence theory. This algorithm can provide effective solutions to problems of optimization through intelligence created from complex activities such as cooperation and competition between individuals in the biology colony (Kennedy J. 2011). PSO still retains the population-based global search approach opposed to evolutionary computations, and its velocity displacement search method is simple and easy to implement. This algorithm also prevents the creation of complex genetic operators such as crossover and mutation. The PSO algorithm has been successfully applied to complex non-linear function optimization (Shi et al., 1999), assignment (Salman et al., 2002), reactive power and voltage control (Salman et al., 2002) etc. Given the relative limitations of Genetic Algorithm (GA) based training technique, where there is tendency of the algorithm being trapped when approaching the optimum, and issue of local convergence.

This paper addresses the problem of diagnosing patient with heart disease thereby reducing the cost in terms of time and money, removing the complication of Angiography and improving the overall medical system by improving its accuracy. Although, Angiography is the best and the most accurate method for the diagnosis of CAD, but Angiography has significant complications, which include allergic reaction of contrast dye, warm feeling with metallic taste, kidney damage, trouble with breathing, blood clot etc. Study has shown using data mining tools and techniques to deal with this issue (Singla *et al.*, 2014). The paper aim to develop a hybrid system, as an optimization task, using a meta-heuristic technique, PSO is used to train Deep Neural Network, thereby improving the accuracy of the system. The system could give doctor a helping hand for effective treatment and early diagnosis for this silent killer (Heart disease). After the introductory section, the rest of the paper is organized into different section, The following is a description of the remaining section of the paper, each concentrating on the different characteristics of the research work; Section A offers related work and its limitations in addition to other classification methods suggested for the diagnosis of heart disease. Section B addresses the research methodology, including the origins of this study's data collection, implementation technology, PSO algorithm. Section C entails the result and discussion. Finally conclusion and future work is concluded in Section D.

## RELATED WORK

Mohammed (2012) in table 1 proposed a selection strategy using a binary particle swarm optimization algorithm to diagnose various medical conditions. The vector supporting system was used to optimize the binary particle swarm fitness function. The suggested approach was tested on four machine learning database, including the computed tomography heart database with single proton emission, the Wisconsin breast cancer data set, the Pima Indians diabetes database, and the Dermatology data set. The results indicate that higher accuracy was obtained in diagnosing heart disease, cancer, diabetes, and erythematosquamous diseases with fewer selected features. The results were compared with the traditional methods of selection of features, namely the F-score and the gain of information, and the proposed method obtained a superior accuracy. The results of the proposed method show a higher accuracy in all details, except in one, compared to the genetic algorithm for feature selection In addition the proposed approach has higher performance using fewer features compared to other approaches that used the same data.

Nagy *et.al*, (2012) introduced a computer-aided heart valve disease diagnostic method using binary particle swarm optimization and vector support tool, in combination with K-nearest neighbour and cross-validation leave-one-out. The method was implemented in a representative heart dataset of 198 heart sound signals, both from stable medical cases and from the four most severe heart valve diseases: Aortic Stenosis (AS), Aortic Regurgitation (AR), Mitral Stenosis (MS) and Mitral Regurgitation (MR). The proposed method starts with an optimization of binary particle swarm based algorithm to select the weighted characteristics. This is accompanied by a support vector machine to classify the cardiac signals into two outcomes: stable or cardiac valve disease, then the cardiac valve disease is categorized into four outcomes: AS, AR, MS, and MR. The experimental results obtained indicate that the overall reliability of the method is high compared to other techniques (Ghadiri, 2014). The proposed method starts with an optimization of binary particle swarm based algorithm to select the weighted characteristics. This is accompanied by a support vector machine to classify the cardiac signals into two outcomes: stable or cardiac valve disease, then the cardiac valve disease is categorized into four outcomes: AS, AR, MS, and MR. The experimental results obtained indicate that the overall reliability of the method is high compared to other techniques. The data sets from the University of California Irvine (UCI) on coronary artery disease were used to validate our new approach to classification. Results show that with acceptable accuracy the proposed method can detect coronary artery disease. The rules that have been discovered also have considerable interpretability.

Durairaj et al. (2015) proposed a pre-processing technique for the data set and the use of the feature reduction PSO algorithm. The predictive accuracy is tested after applying the PSO. It is observed from the experiments, a possible result in the prediction of 83 percent accuracy. PSO algorithm output is then compared with the algorithm Ant Colony Optimization (ACO). The experimental results show that PSO's accuracy is better than ACO's accuracy. The metrics of performance are based on accuracy, tolerance, and specificity. Certain tests such as Kappa numbers, Mean Absolute Error, Root Mean Squared Error, and True Positive Rate are also being used for evaluation.

Caliskan and Yuksel, (2017), proposed a Deep Neural Network Based classifier for CAD data sets identification for CAD diagnosis purposes. The method was tested on data sets from Cleveland, Hungary, VaLongBeach and Switzerland, experimental results indicate that the proposed method provides the highest reliability of classification among the methods included in the experiments. It is assumed that for the diagnosis of CAD, the proposed classifier based on DNN can be used to classify clinical CAD datasets. Experimental results show that the Deep Neural Network outperform other methods like DecisionTable, NaiveBayes, Logistic, Random Forest and Bagging. But Caliskan and Yuksel, (2017) model wasn't able to escape in the entrapment of local optimum, there by not able to attain a higher accuracy.

Dulhare (2018) proposed a Naive Bayes (NB) classifier that is relatively stable in terms of small variations or changes in training data and PSO that is an effective adaptive computing technique which selects the best features that contribute more to the result which reduces computation time and improves accuracy. The experimental result shows that the proposed model with PSO as selection of features improves the Naive Bayes ' predictive accuracy in classifying heart disease.

Table 1: Related Work

| **Author/s:** | **Method used** | **Problem solved** |
|---|---|---|
| Daliri (2012) | Binary PSO and Support Vector Machines | Diagnosing heart diseases |
| Nagy *et al.* (2012) | Binary PSO – KNN-SVM | Diagnosing heart diseases |
| Ghadiri and Saniee (2014) | Fuzzy-Boosting + PSO | Diagnosing heart diseases |
| Durairaj and Sivagowry (2015) | Feature Diminution + PSO | Diagnosing heart diseases |
| Caliskan and Yuksel (2017) | Deep Neural Network | Diagnosing heart diseases |
| Dulhare (2018) | Naive Bayes+GA<br>Naive Bayes+PSO | Diagnosing heart diseases |
| **Abdulsalam *et al.*, (2019)** | **DNN + PSO** | **Diagnosing heart diseases** |

## METHODOLOGY

In this research work PSO is used in training Deep Neural Network to avoid if from being trapped in the local optimum. This section include means for the research work, Conceptual model, Implementation technology and finally the architectural frame work. Fig. 1 represents the conceptual model. It starts by collecting four different medical data for CAD, which are collected from data mining repository of the University of California, Irvine (UCI) Machine learning repository then it undergo data pre-processing where missing values is handled by mean substitution method , then it proceeds to the classification model, where the Particle Swarm Optimization is used in training Deep Neural Network to classify the data as being diagnosed with CAD or normal, and finally the output of the system is utilized by authorized medical healthcare personnel (Doctor).This system could give the doctor a helping hand for effective treatment and early diagnosis of Heart disease.

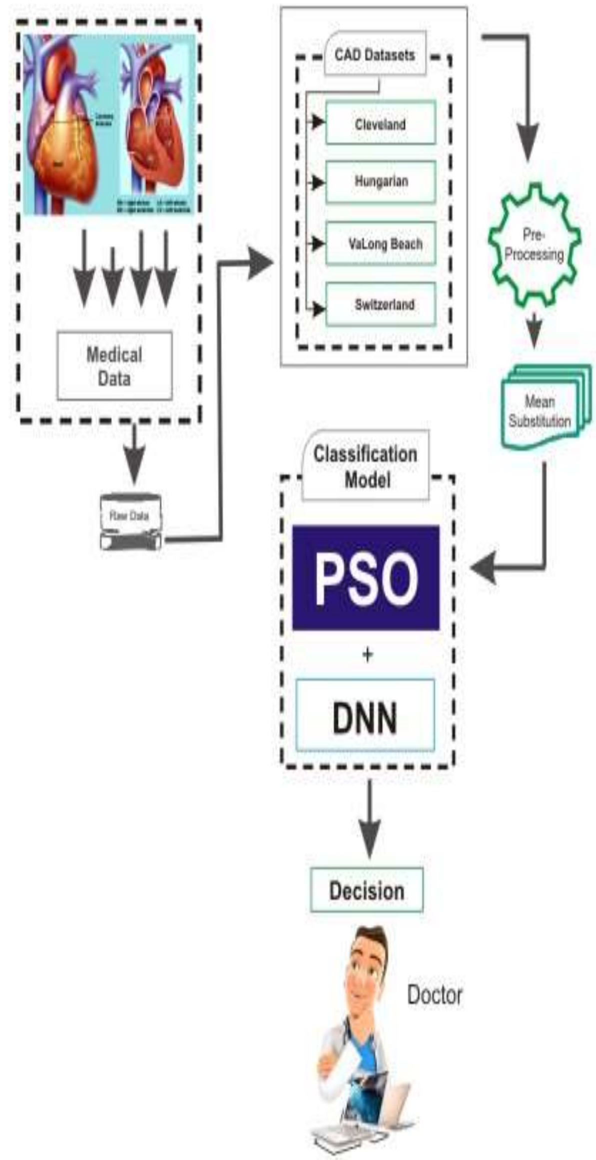


*Fig*. 1: Conceptual Model

### IMPLEMENTATION TECHNOLOGY

In this research work Python programming language is used. Python is a general scripting language which has a clear and straightforward syntax. With the rapid development of mature, advanced and open source scientific computing libraries and packages, Python became a standout amongst the most popular and ground-breaking languages for scientific computing. In addition, Python has cross-platform run ability, which works with different operating systems Windows, Linux, Ubuntu etc. Python has ability to access libraries written in different programming languages and computing environments. Python support small devices form, embedded systems, and microcontrollers. Additionally, Python needs very minimal setup procedure to start with. Python uses modular and object based programming, which is a popular methodology to organize classes, functions, and procedures into hierarchical namespaces. All these reasons have turned Python to be a popular language in a tremendous community of scientists. The implementation uses the fast array manipulation using Numerical Python 'NumPy '(http://www.numpy.org/). Matrix support using Scientific Python SciPy` (https://www.scipy.org/) package. Specifically for binary classification problem. The implementation uses of a powerful Neural Network Library [`neurolab`] (https://pythonhosted.org/neurolab/) `Home Page <http://code.google.com/p/neurolab/>

### PSO ALGORITHM

Particle swarm optimization (PSO) is an evolutionary optimization calculation method that was originally developed in 1995 by Kennedy and Eberhart. It is inspired by bird flocking or fish schooling and swarm theory's social behaviour. This algorithm operates by preserving in the search space at the same time some of the candidate solutions. In the dimensional search space, each candidate solution is called a particle "flying" to find the best solution. That candidate solution is evaluated by the objective function in all the iterations of the algorithm, and the fitness of that solution is determined. The PSO algorithm, like the GA, is initialized with a random population. Originally, like the GA, a search space population of random solutions initializes the PSO algorithm. PSO also only needs the information related to the fitness values of the population's particles. By using the objective function, this algorithm precisely measures the individual's fitness values. Similar to a genetic algorithm, individuals in PSO have a memory in order to maintain that individual's knowledge about the particles with better solutions. It creates a constructive cooperation between each individual, in other words, and the individuals share information among themselves.

**The Algorithm**

For each particle

Initialize particle

End

Do

For each particle

Calculate fitness value

If the fitness value is better than its personal best

Set current value as the new Pbest

End

Choose the particle with the best fitness value of all as gbest

For each particle

Calculate particle velocity

Update particle position

End

**Pseudocode of Particle Swarm Optimization**

PSO algorithm consists of three (3) steps, PSO:

(1) Calculate the fitness value of each particle.

(2) Update local and global best positions and fitness

(3) Now calculate each particle's new velocity and position as to where the inertia weight applied to control the effect of the previous velocity history.

Original PSO (Kennedy, 1997) is inspired by birds ' flocking behaviour. The knowledge of the best-found global solution (typically noted gBest) is shared among the swarm's agents (parts). In addition, each particle has its own (personal) best-funded (noted pBest) memory. The last important part of the algorithm is the velocity of each particle that is taken into account when measuring the motion of the particles.

The new position of each Particle is then given by (1), where $x_i^{t+1}$ is the new particle position; $x_i^t$ refers to current particle position and $v_i^{t+1}$ is the new velocity of the particle.

$$x_i^{t+1} = x_i^t + v_i^{t+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

The distance from pBest and gBest is taken into account in the estimation of the new velocity alongside the current velocity as shown in the formula (2)

$$v_i^{t+1} = w \cdot v_{ij}^t + c_1 \cdot Rand \cdot (pBest_{ij} - x_{ij}^t) + c_2 \cdot Rand \cdot (gBest_{ij} - x_{ij}^t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

$v_i^{t+1}$ - New velocity of the ith particle in iteration *t* + 1. (Component *j* of the dimension D).

$w$ - Inertia weight value

$v_{ij}^t$ - -Current velocity of the ith particle in iteration t.

*c1, c2* - Acceleration constants.

$pBest_{ij}$ - Local (personal) best solution found by the ith particle.

$gBest_{ij}$ - Best solution found in a population.

$x_{ij}^t$ -Current position of the ith particle in Iteration *t*.

***Rand*** - Pseudo random number, interval (0, 1).

After the movement, the particle evaluates the quality of its new position and compares it with its personal best solution (*p*Best). If a better value was discovered, the *p*Best is updated. Similarly, if the new best solution in the neighborhood (swarm or sub-swarm) was discovered, the gBest is updated.

The basic PSO algorithm consists of the positions and velocities of the particles, update the velocity, and finally update the positon. A particle here refers to a point in the design space that shifts its location from one motion (iteration) to another based on updates of velocity. First, on the model variables values, the positions and velocities of the initial swarm of particles are generated randomly using upper and lower limits, rand is a uniformly distributed random variable that can take any value from 0 to 1. This initialization process allows for the random distribution of the swarm particles throughout the design space. The second step is to update all particle speeds using the objective or fitness values of the particle that are functions of the current positions of the particle in the design space. A particle's fitness function value determines which particle in the current swarm has the best global value and also determines the best position of each particle, i.e. in current and all previous movements. The velocity update equation uses these two pieces of information to provide a search path for the next iteration for each particle in the swarm along with the effect of current motion. The velocity update formula includes some random parameters, represented by the uniformly distributed variables, rand, in order to ensure good design space coverage and avoid local optima trapping. The three values that affect the new search direction, namely current motion, particle-own memory, and swarm influence, are incorporated through a summation approach with three weight factors, namely inertia factor, w, factor of self-confidence, c1, and factor of confidence in swarming, c2. The three steps of velocity update, position update, and fitness calculations are repeated until a desired convergence criterion is met. There has been no recommendation in the literature regarding swarm size in PSO. Most researchers use a swarm size of 10 to 50 but there is no well-established guideline. This research uses the population Size = 100 and number of Iterations= 10. The dataset is split into two (2) 64% for training and 36% for testing for each dataset Cleveland, Hungarian, Switzerland and VaLongBeach.

**ARCHITECTURAL FRAMEWORK**

The architectural work start by dividing the dataset into two parts using 10-fold cross validation, where the train dataset is divided into 64% and test into 36%. The train dataset undergo feature selection. PSO algorithm generate initial particles and calculate the fitness value of each particle, if the current fitness value is better than pBest then it assign current fitness as new pBest or else it keeps the previous pBest then it assign best particle (pBest) value to gBest, calculate the velocity for each particle velocity value to the update of the data values, if the target or maximum epoch is reached, it select the best individual as the initial weight of DNN or else it goback and calculate fitness valued each particle, then the output of DNN is calculated, if the stopping criterion is satisfied the test dataset is classified using DNN or else the weight is updated until the stopping criterion is satisfied. The architectural framework Hybrid method for CAD detection method, is shown in Fig. 2

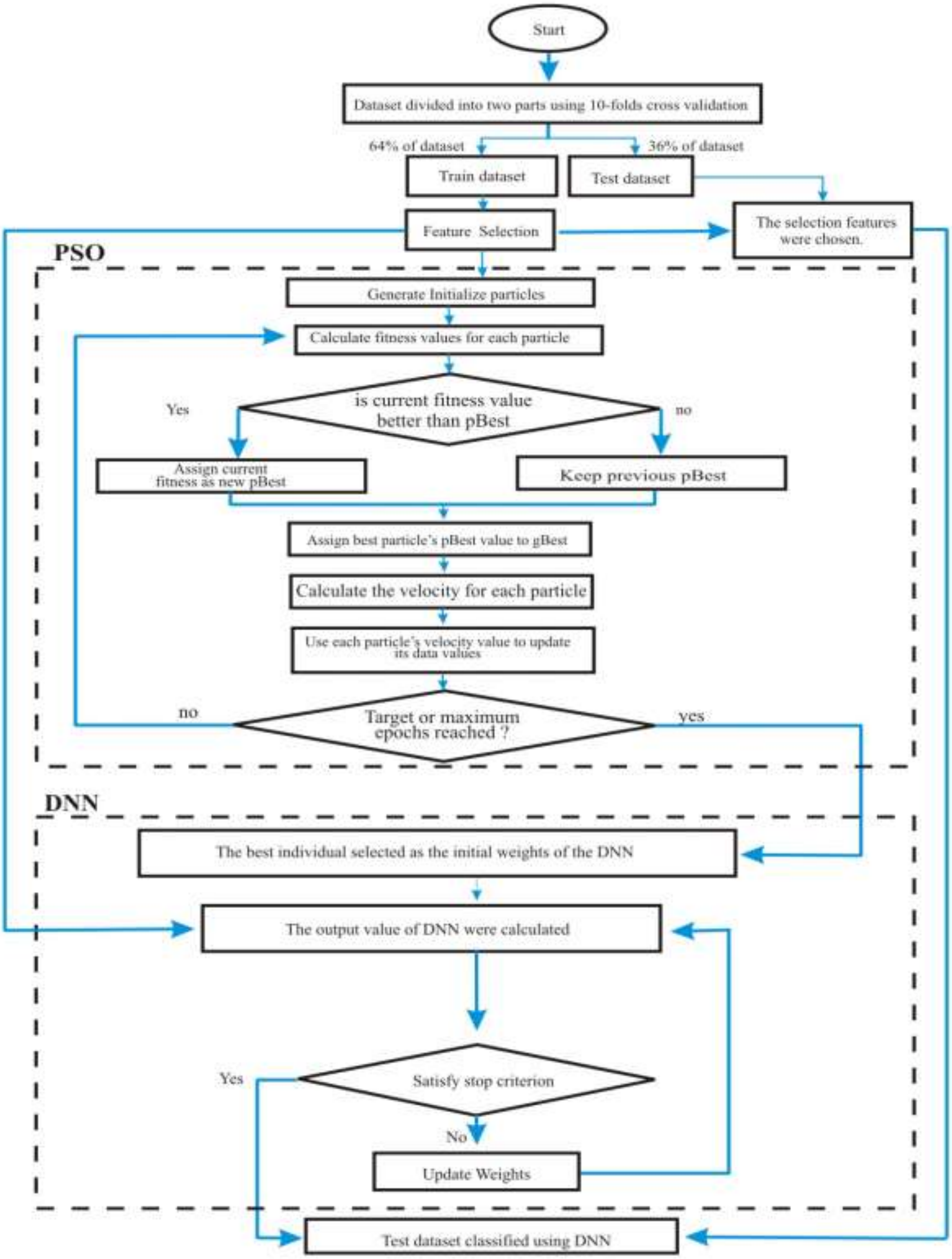


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Fig. 2: Hybrid Method for CAD

## RESULTS AND DISCUSSION

Tables 2 indicate the comparison of the accuracy for the existing method and Abdulsalam et al., (2019) method. Deep Neural Network could only achieve 85.2%, 83.5%, 92.2% and 84% for Cleveland, Hungarian, Switzerland and VaLongBeach respectively, but Abdulsalam et al., (2019) that uses Deep Neural Network training with PSO was able to achieve 94%, 94.9%, 95.5% and 95.0% accuracy. Figure 3 shows the graphical representation of the Accuracy according to its representation in Table 2.

**Table 2: Evaluating the Accuracy of Abdulsalam et al., (2019) and existing method**

| Data sets | Accuracy | | |
|---|---|---|---|
| | Existing Method | Abdulsalam *et al.*, (2019) | Performance difference |
| Cleveland | 85.2% | 94% | 8.8% |
| Hungarian | 83.5% | 94.9% | 11.4% |
| Switzerland | 92.2% | 95.5% | 3.3% |
| VaLong Beach | 84% | 95.0% | 11.0% |

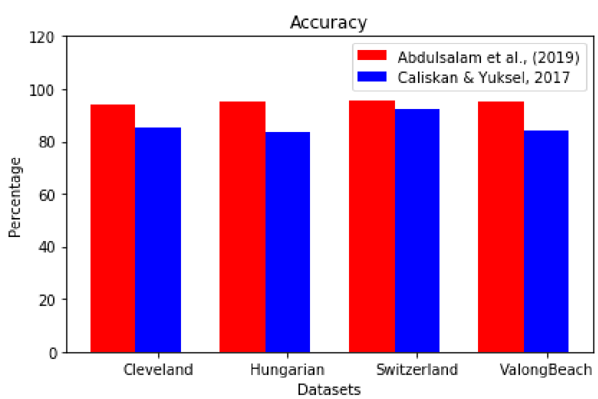


Fig. 3: Accuracy of existing and Abdulsalam et al., (2019)

**Table 3: Evaluating the Sensitivity of Abdulsalam et al., (2019) and the existing method**

| Data sets | Sensitivity | | |
|---|---|---|---|
| | Existing Method | Abdulsalam *et al.*, (2019) | Performance difference |
| Cleveland | 97.67% | 99% | 1.3% |
| Hungarian | 92.73% | 99.7% | 7.0% |
| Switzerland | 78% | 99% | 21.0% |
| VaLong Beach | 93% | 99% | 6.0% |

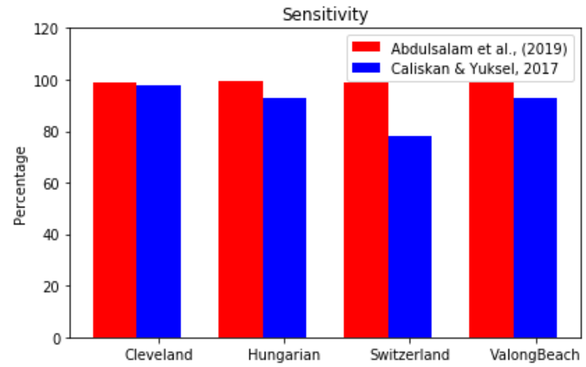


Fig.4: Sensitivity of existing with Abdulsalam *et al.*, (2019)

**Table 4: Evaluating the Specificity of Abdulsalam *et al.*, (2019) and the existing method.**

| Data sets | Specificity | | |
|---|---|---|---|
| | Existing Method | Abdulsalam *et al.*, (2019) | Performance difference |
| Cleveland | 78.26% | 90% | 11.7% |
| Hungarian | 82.61% | 90% | 7.4% |
| Switzerland | 80% | 92% | 12.0% |
| VaLong Beach | 83% | 90% | 7.0% |

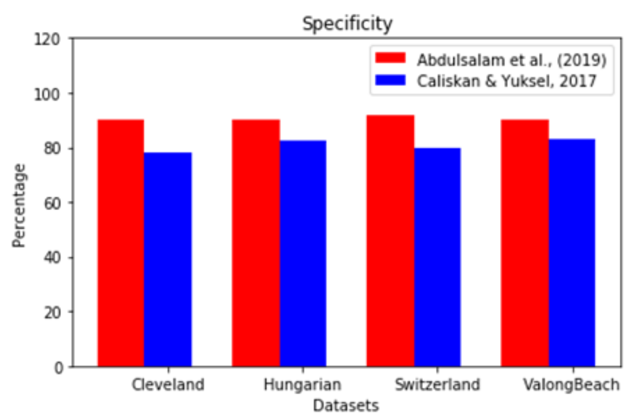


Fig. 5: Specificity of existing and Abdulsalam *et al.*, (2019)

Tables 5 show the results of confusion matrix for Cleveland, Hungarian, VerlongBeach and Switzerland dataset.

**Table 5: Confusion Matrix Result**

| Data | Confusion matrix | | Dataset |
|---|---|---|---|
| 1 | Accuracy = 94 | TN = 91.79 | Cleveland |
| | Sensitivity = 99 | FP = 9.93 | |
| | Specificity = 90 | FN = 0.29 | |
| | | TP = 93.18 | |
| 2 | Accuracy = 94.9 | TN = 95.53 | Hungarian |
| | Sensitivity = 99.7 | FP = 9.85 | |
| | Specificity = 90 | FN = 0.27 | |
| | | TP = 94 | |
| 3 | Accuracy = 95.0 | TN =96.06 | Valongbeach |
| | Sensitivity = 99 | FP =42.47 | |
| | Specificity = 90 | FN =0.21 | |
| | | TP =94.98 | |
| 4 | Accuracy = 95.5 | TN =93.93 | Switzerland |
| | Sensitivity = 99 | FP= 7.53 | |
| | Specificity = 92 | FN= 0.23 | |
| | | TP= 95 | |

**Table 6: Result comparison of Abdulsalam *et al.*, (2019) method with some Meta heuristic methods**

| Method used | | Accuracy | Sensitivity | Specificity |
|---|---|---|---|---|
| Roostaee and ghaffary, 2016 | GA-ANN | 81.11 | 77.74 | 80.66 |
| | GA-ANN+PCA | 80.74 | 74.41 | 80.66 |
| | COA-ANN | 82.22 | 78.64 | 83.74 |
| | COA-ANN + PCA | 82.96 | 80.37 | 83.59 |
| Arabsadi, 2017 | GA-NN | 89.4 | 88 | 91 |
| Abdulsalam et al., (2019) | PSO + DNN | 95.5 | 99 | 92 |

Table 6 compares the result of Abdulsalam *et al.*, (2019) with some of the Meta heuristic, algorithm like Genetic Algorithm with Artificial Neural Network, GA-Ann with Principal Component analysis, Cuckoo Optimization Algorithm with Neural network, COA+ANN with Principal Component Analysis, Genetic algorithm with Neural network and Fig. 6 is the corresponding graph.

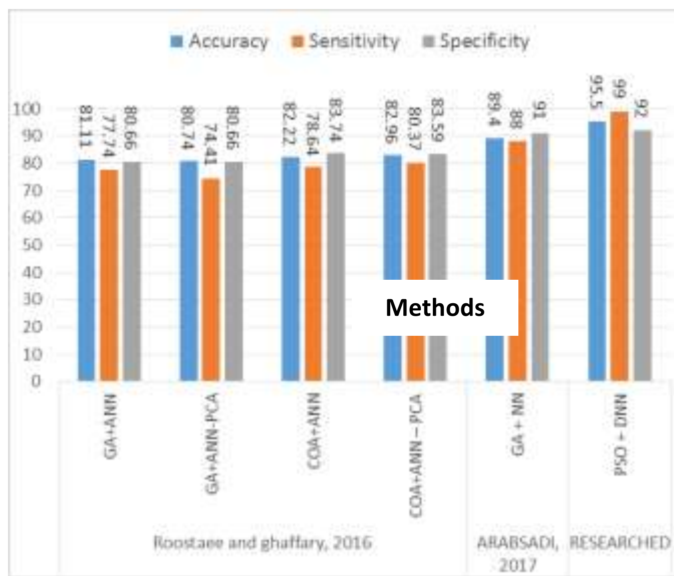


Fig. 6: Comparison of Abdulsalam *et al.*, (2019) with some Meta heuristic methods

## CONCLUSION AND FUTURE WORKS

The proposed method uses Particle Swarm Optimization (PSO) to train Deep Neural Network which avoids the entrapment in the local optimum and apply it to the diagnosis of heart disease. Experimental results show that improvements by 8.8%, 11.4%, 3.3%, and 11.0% for Cleveland, Hungarian, Switzerland, and VaLongBeach respectively, which improve the classification performance. PSO has shown a speedy convergence towards global optimum and escape in the entrapment in the local optimum due to its efficient global search procedure. The proposed method can be used for CAD detection. In addition to the Particle Swarm Optimization algorithm, there are many strong metaheuristic algorithms such as Ant Colony that are evolutionary and nature-inspired Optimization (ACO), Grey Wolf Optimizer, Whale Optimization Algorithm, Fire fly etc. As for the future works, one of these methods can be used to experiment to see if there is any further improvement.

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