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***Research paper***

# Multilayer Neural Network Approach in Heart Disease Prediction: Investigating a Framework

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## Abstract

The early detection of heart disease is vital to avoid sudden death. There are several symptoms that are familiar to heart disease patients. By analyzing the symptoms and assist with ECG signal's pattern, doctors would be able to confirm the heart disease. Since the conventional method of heart disease detection is quite tedious, the automatic detection is proposed. To automate the early detection, a number of adequate algorithms have been proposed in many studies. The algorithms receive input of patients' details and generate the predicted result. Therefore, this study is proposed to implement and investigate the performance of multilayer neural network (MNN) approach in producing the heart disease prediction.

***Keywords***: *multilayer neural network, heart disease, computer-aided detection.*

## 1. Introduction

Soft computing or computational intelligence is interpreted as a technique applied to mimic the understanding the natural phenomena. It involves the development of complex mathematical algorithms. Some of the trending computing algorithms are a neural network, genetic algorithm, fuzzy logic and ant colony optimization [1, 2]. The latest research works in computational intelligence have shown a rapid trend of applying the algorithms in the field of medicine, especially for early disease detection [1, 3].

Heart disease or cardiovascular disease is considered as one of the main cause of death Malaysia [4]. Another survey in Malaysia has determined heart failure to be the reason for death among the children and adults [5]. In addition, it has been reported that in Malaysia, ischemic heart diseases was the principal cause of death in 2016 of 13.2% [6]. In a wider view, heart disease is reported to be the main cause of death in the world as well [7].

Early recognition of irregular heart conditions can avoid sudden cardiovascular passing and different risky sickness brought about by coronary illness. Numerous investigations have reported that the most used methodology of tracing the strange heart conditions is through examining the ECG [8]. In another hand, valvular heart disease (VHD) that is defined as the affection of the heart valves can be detected by Doppler echocardiography [9]. However, this method is rather expensive, requires qualified expertise, discontinuous, and complicated. Other methods in practice are by executing the angiography test and analysing the patients' health history, physical examination, and the symptoms where the medical experts are needed. Typically, these methods would lead to diagnosis delay and human errors [10, 11].

To solve the errors and delays, numerous medical decision support system based on artificial intelligence methods have been proposed and developed. There are several popular computational methods have been proposed; support vector machine, k-nearest neighbour [9], decision tree, fuzzy logic and artificial neural network [12, 13]. However, multilayer neural network (MNN) is the most proposed method in medical diagnosis due to its ability in handling complex problem [10, 14].

A study carried out by Awang & Siraj [14] has used ANN to predict heart failure with the accuracy of 88.89%. Arabasadi, Alizadehsani, Roshanzamir, Moosaei, & Yarifard [15] applied ANN in the detection of heart disease. The neural network in the work resulted in accuracy of 93.85%. Another recent work by Samuel et. al. [12] utilizes ANN in predicting heart failure with 91.1% accuracy.

Even though ANN-based system and model is considered helpful in heart disease and failure diagnose, it has a major limitation where the attributes of the prediction are assumed to have identical weight on the outcome. This is contradicted by studies in medical fields that report the heart disease analysis attributes must have a different degree of weights [15].

To solve the weighing problem, multi-criteria decision-making methods have offered various techniques, namely analytic hierarchy process (AHP), simple additive weighting (SAW), multi-attribute utility theory (MAUT), and TOPSIS. In addition, optimization method like the genetic algorithm is recently used to produce a set of accurate weights [12].

In this paper, a computer-aided diagnosis system is proposed to detect the symptoms of heart disease failure. In order to achieve this goal, several patient's data need to be collected. Then, the data is calculated by the MNN engine. The MNN engine is previously trained by using sample dataset. The purpose of the training is to gain knowledge of the symptoms of the disease. Therefore, the system can produce accurate results based on the trained knowledge.

## 2. Methods and Material

### 2.1 Dataset

This study uses the Cleveland dataset [16] with 76 attributes. This data set is chosen because of the regularity in testing purposes [12, 17]. The data is separated by 200 and 50 training and testing data. The collection of data consists of the values of attributes for the main factors and symptoms of heart disease. However, for this study, 13 attributes are chosen as shown in Table 1. The 200 sets of training data are used to extract the output values of two classes which indicate the presence of heart disease (presence) and the absence of heart disease (absence).

**Table 1:** Attributes of data description and representation

| Attribute | Attribute Code | Range Data |
|---|---|---|
| Age | age | 30 - 70 |
| Gender | gen | Male [0]<br>Female [1] |
| Chest pain type | cpt | Typical angina [1]<br>Atypical angina [2]<br>Non-angina pain [3] |
| Resting blood pressure | rbp | Low [< 128]<br>Medium [128 - 142]<br>High [143 - 154]<br>Very High [> 154] |
| Serum cholesterol | sch | Low [< 188]<br>Medium [189 - 217]<br>High [218 - 281]<br>Very High [> 281] |
| Fasting blood sugar | fbs | True [1]<br>False [0] |
| Resting electrocardiographic result | res | Normal [0]<br>ST-T abnormal [1]<br>Hypertrophy [2] |
| Maximum heart rate achieved | mhr | Low [< 112]<br>Medium [112 - 152]<br>High [> 152] |
| Exercise-induced angina | eia | True [1]<br>False [0] |
| Old peak | opk | Low [< 1.5]<br>Risk [1.5 - 2.55]<br>Terrible [> 2.55] |
| Peak exercise slope | pes | Up-sloping [1]<br>Flat [2]<br>Down-sloping [3] |
| Number of major vessels coloured by fluoroscopy | vca | Fluoroscopy - 0 [0]<br>Fluoroscopy - 1 [1]<br>Fluoroscopy - 2 [2]<br>Fluoroscopy - 3 [3] |
| Thallium scan | tha | Normal [3]<br>Fixed defect [6]<br>Reversible defect [7] |

### 2.2 Proposed Method

In this section, multilayer neural network algorithm is implemented to predict heart disease. Figure 1 shows the framework of the algorithm. The process needs to accept 13 input data and they are processed in 5 steps in the algorithm.

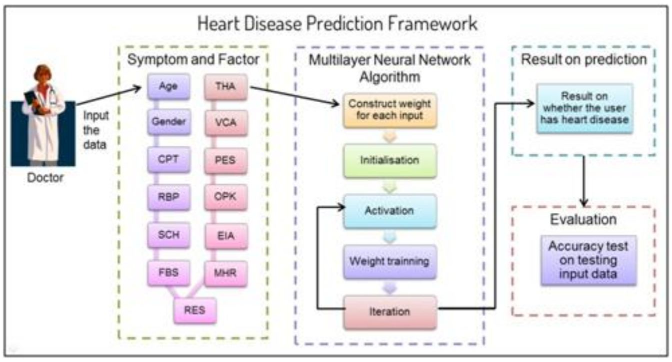


**Fig. 1:** The Framework

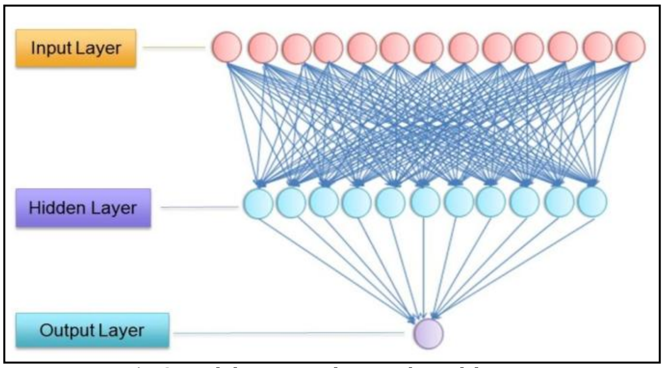


**Fig. 2:** Multilayer Neural Network Model

The process starts when the user inserts the input stated in Table 1 where each of the input has its own range of values. After all the input is completed, then the network for MNN is constructed. The 13 input layers produce 10 hidden layers and 1 output layer as shown in Figure 2. Then, 4 steps of MNN algorithm (initialization, activation, weight training, and iteration) are carried out [1, 10, 18].

Initialization

In this step, each input - hidden, hidden - output weight is initializing and set the threshold value for each node. First, compute a net weight by using these formulae:

$$\left(-\frac{2.4}{F_i}, +\frac{2.4}{F_i}\right) \tag{1}$$

Where $F_i$ is the total number of input network. The weight is done on a neuron - by neuron basis.

Activation

Calculate the actual output in the hidden layer:

$$y_j(p) = \text{sigmod}\left[\sum_{i=1}^{n} x_i(p) * w_{ij}(p) - \theta_j\right] \tag{2}$$

Calculate actual output in output layer:

$$y_k(p) = \text{sigmod}\left[\sum_{j=1}^{m} x_{jk}(p) * w_{jk}(p) - \theta_k\right] \tag{3}$$

*Weight Training*

Calculate error gradient in output layer:

$$w_{jk}(p+1) = w_{jk}(p) + \Delta w_{jk}(p) \tag{4}$$

Calculate error gradient in the hidden layer:

$$w_{ij}(p + 1) = w_{ij}(p) + \Delta w_{ij}(p) \tag{5}$$

Where $w_{ij}$ represent as the weight of each layer in the back-propagation, $\alpha$ as the input in the first layer, $x_{ij}(p)$ as the first hidden layer in back-propagation, $y_k(p)$ as the second hidden layer in back-propagation and $\theta_k$ the calculation from output layer.

*Iteration*

In this step it will increase the value of p by one, go back to step 2 and repeat the process until the selected error criterion is satisfied.

## 3. Result and Discussion

Step 1: Construct input, hidden and output layer for the neural network. The example of neural network model can refer to Figure 2.

Step 2: Initialization

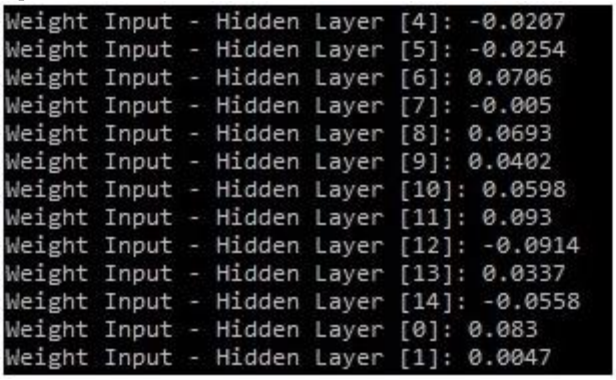
```
Weight Input - Hidden Layer [4]: -0.0207
Weight Input - Hidden Layer [5]: -0.0254
Weight Input - Hidden Layer [6]: 0.0706
Weight Input - Hidden Layer [7]: -0.005
Weight Input - Hidden Layer [8]: 0.0693
Weight Input - Hidden Layer [9]: 0.0402
Weight Input - Hidden Layer [10]: 0.0598
Weight Input - Hidden Layer [11]: 0.093
Weight Input - Hidden Layer [12]: -0.0914
Weight Input - Hidden Layer [13]: 0.0337
Weight Input - Hidden Layer [14]: -0.0558
Weight Input - Hidden Layer [0]: 0.083
Weight Input - Hidden Layer [1]: 0.0047
```

**Fig. 3:** Result for input - hidden layer weight

Figure 3 shows the sample result for input - hidden weight that been calculated by the formula (1).

Step 3: Activation

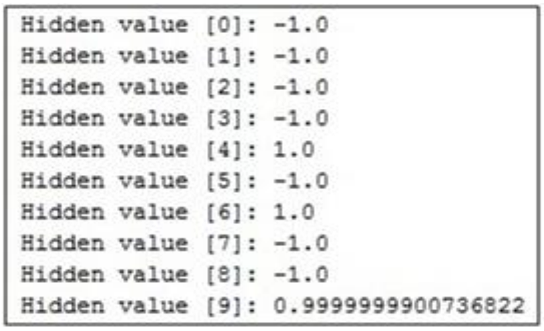
```
Hidden value [0]: -1.0
Hidden value [1]: -1.0
Hidden value [2]: -1.0
Hidden value [3]: -1.0
Hidden value [4]: 1.0
Hidden value [5]: -1.0
Hidden value [6]: 1.0
Hidden value [7]: -1.0
Hidden value [8]: -1.0
Hidden value [9]: 0.9999999900736822
```

**Fig. 4:** Result from actual output on hidden layer

Figure 4 shows the sample result for actual output on the hidden layer by applying the formulae (2) and formulae (3) gives the result for the output layer.

Step 4: Weight Training

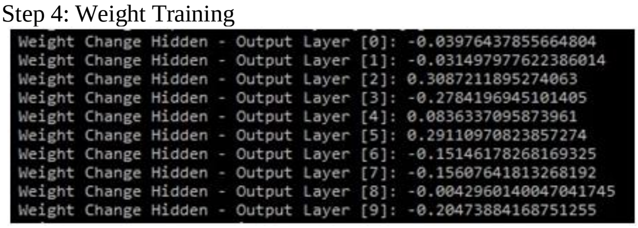
```
Weight Change Hidden - Output Layer [0]: -0.03976437855664804
Weight Change Hidden - Output Layer [1]: -0.031497977622386014
Weight Change Hidden - Output Layer [2]: 0.3087211895274063
Weight Change Hidden - Output Layer [3]: -0.2784196945101405
Weight Change Hidden - Output Layer [4]: 0.0836337095873961
Weight Change Hidden - Output Layer [5]: 0.29110970823857274
Weight Change Hidden - Output Layer [6]: -0.15146178268169325
Weight Change Hidden - Output Layer [7]: -0.15607641813268192
Weight Change Hidden - Output Layer [8]: -0.0042960140047041745
Weight Change Hidden - Output Layer [9]: -0.20473884168751255
```

**Fig. 5:** Example of weight change for hidden - output layer

Figure 5 shows the result of weight change for hidden - output layer which calculated by formulae (5) and formulae (4) gives the result for output layer weight change.

Step 5: Iteration

For this step, the MNN will repeat step 3 until the number of error is less than 0.001.

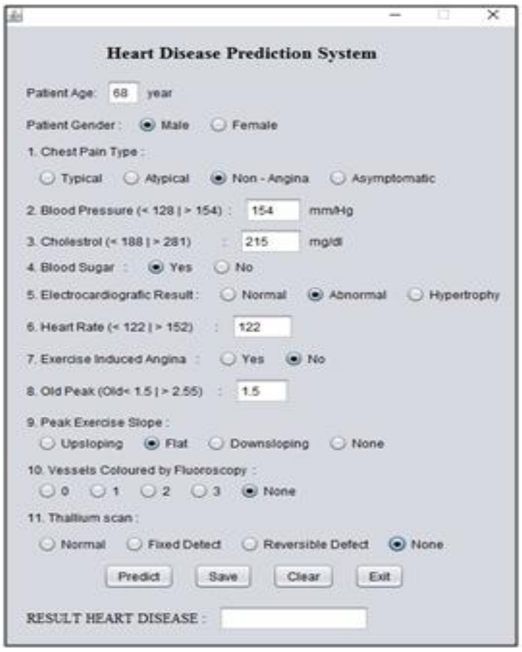


**Fig. 6:** Sample of input

Figure 6 shows the example of input patient data into the system. After user click button "Predict" it will show the result of the prediction.

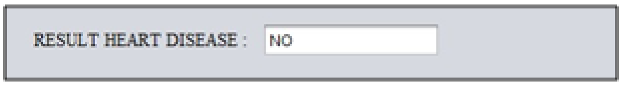


**Fig. 7:** Example result for prediction

Figure 7 shows the result for the prediction on heart disease for the patient in Figure 6.

*Evaluation Analysis*

The result of this study is evaluated by using accuracy test which calculates the true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The formulae for the accuracy test are:

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + FP + TN + FN)} \tag{6}$$

Where TP as true positive which is the actual value of predict [1] is correctly predict by the system, TN as true negative which is the actual value of predict [0] is correctly predict by the system, FP as false negative which is the predict [0] is incorrectly predict by the system and FN as false negative which is the predict [1] is incorrectly predict by the system.

**Table 2:** Accuracy test result

| | Predicted Value |
|---|---|
| True Positive (TP) | 0 |
| True Negative (TN) | 25 |
| False Positive (FP) | 0 |
| False Negative (FN) | 25 |
| Accuracy (%) | 50 |

Table 2 shows that the total accuracy of this project and the analysis of true positive (TP), true negative (TN), false negative (FN) and false positive (FP). As known, TP represent of predicting the correct output with correct answer predicted by the system, TN represents the incorrect output with incorrect answer predicted by the system, FP represents the correct output is predicted wrongly by the system and FN the incorrect output is predicted correctly by the system. For this system, TN and FN have the same value which is 25 where TP and FP value is 0. This can conclude that this algorithm is not strong enough to predict heart disease since the accuracy is 50%.

## 4. Conclusion

In this paper, we proposed and investigated a computer-aided diagnosis system for the detection of heart disease by using Multilayer Neural Network (MNN). The proposed methodology utilized 200 sets of training data and 50 sets of testing data. The methodology begins with receiving the input of patient's 13 attributes. Then, the MNN engine started to calculate the possibilities of heart disease in 5 steps; construct input, hidden and an output layer; initialization; activation; weight training; and iteration. To verify the method accuracy, an accuracy test is carried out. The result shows that using MNN method in predicting heart disease is only 50% accurate. Therefore, it is suggested that MNN should be combined with other methods like genetic algorithm [19] and fuzzy-AHP [12, 19].

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