Diagnosis for Heart Disease Using Neural Network

Dr. Nabeel T. Alshohybe
Dept. of Information Technology,
Faculty of Computer and Information Technology, Sana'a University
Sana'a, Yemen

Dr. Ghaleb H. Al-Gaphari
Dept. of Computer Science,
Faculty of Computer and Information Technology, Sana'a University
Sana'a, Yemen

Abstract*— worldwide, heart disease is considered a major health problem that affects a large number of people. According to the world health organization, heart disease is the first leading cause of death in high and low-income countries. The disease does not differentiate between both genders and it occurs almost equally in men and women [1]. Heart disease can often be difficult to diagnose because its symptoms can be vague and easily confused with other health problems. Globally, one of the most medical malpractices is the diagnosis error. Data mining is applied to find useful patterns to help in the important tasks of medical diagnosis. The research aims to build the model to diagnosis of the heart disease. Work also aim at increasing the efficiency of the proposed model. The approach adopted here is artificial neural network model, based on symptoms and risk factors. The model is developed using multilayer perceptron network and trained using Cleveland clinic foundation dataset. The back-propagation neural network algorithm implemented trained, validated, tested, the algorithm performance measured and recorded. The result is very promising because the accuracy average of the algorithm is 98.65% which is slightly high compared to the previous related work.

Keywords- heart disease, data mining, neural network, back-propagation, machine learning and classification.

I. INTRODUCTION

Heart disease is considered a major health problem for a significant percentage of people. The diagnosis of heart disease in most cases is not that easy and based on a complex combination of both clinical and pathological data. This complexity leads to the excessive medical costs affecting the quality of the medical care [2]. Medical data mining is a method used to discover hidden information in a database and it has great potential for exploring the hidden patterns in the data sets of the medical domain. Medical science is another field where a large amount of data is generated using different clinical reports and other patient symptoms. Medical informatics discipline occurs when both medicine and information technology meet, which provides measurable improvements in both qualities of care and effectiveness. When there is a huge database that contains a large amount of data, data mining techniques are used to analyze this big collection of data from different perspectives and deriving useful information. Depending on the modeling objective, each data mining technique serves a different purpose. Medical Data mining in healthcare is considered an important and complicated task. As a result, it must perform it accurately and efficiently. Healthcare data mining becomes a very useful tool that attempts to solve real world health problems in diagnosis and treatment of disease. The features of the artificial neural network (ANN) [3]. High accuracy and learning rate. Make it worth trying as an algorithm to the diagnosis of heart disease. In this study, the primary goal is developed for classification of liver patients using neural network classification algorithm depend on some risk factors. To perform classification task of medical data, the neural network is trained using Back propagation algorithm.

II. HEART DISEASE

According to the Sarver Heart Center at the University of Arizona, Cardiovascular or heart disease is a very dangerous disease and a leading cause of death, which accounts for 34% of the death in America [4].

According to the Center, the following are considered risk factors for Heart disease:

The family history of Heart Disease: - A person is at much greater risk of having a cardiovascular disease if his or her parents, grandparents, or any other relative are affected or died of heart disease.

Smoking: - It indicates that the evidence is overwhelming that smoking, first-hand smoking or second-hand exposure, are another leading cause of heart disease, stroke and peripheral vascular disease, and lung disease.

Cholesterol: - The blood lipids (fats) include HDL (good cholesterol) and LDL (bad cholesterol), and any abnormal or high-level lipids are the major contributor to heart disease. It is very important to do a regular check especially at older age since cholesterol increase with age, and if a person is at risk, medication is necessary to lower the LDL or raise the HDL. It is recommended that the ideal ratio at 3.0, which is the total cholesterol divided by HDL cholesterol.

High blood pressure: - High blood pressure also a risk factor for heart disease. It is known as "the silent killer' because it occurs without symptoms in most individual. High blood pressure or hypertension causes tear and wear of the inner lining of the blood vessels, which is very delicate. A person becomes at greater risk, when his or her blood pressure (BP) is higher. Age also a factor in high blood pressure because with the increase of age, the higher the risk of getting a high blood pressure.

Obesity: - Obesity increases the risk of heart disease. It is a complex disorder that involves an excessive amount of fat in a person's body. Obesity is different from overweight in that overweight means weighting too much, and the weight may come from muscle, bone, fat, and/or body water where obesity means there is a lot of body fat in the body.

Lack of physical exercise: - Lack of exercise is a risk factor for both obesity and developing coronary artery disease (CAD). It is recommended to exercise in a regular basis. Walking two miles a day is considered optimal for overall health. Exercise burns calories, activates genes that are beneficial to health, and it is one of the best treatments for anxiety and depression.

III. NEURAL NETWORK

The human brain consists of millions of neurons that are connected to each other. Each of these neurons is connected to thousands of other neurons. These neurons communicate with each other via electrochemical signals. The way this communication works: the neuron receives a signal via the synapses, which is a junction located at the end of the neuron branch. Then the neuron performs a processing and generates an output signal.

Neural Network (NN) is simulating the brain process, mentioned above, electronically meaning that the made-up neurons in the Neural Network are an electronically modeled biological neuron. These neurons and the weighted interconnections perform the processing computation and send the output to other neurons. During the training phase, we adjust the weights of the interconnections to produce the desired output [4].

One of the most common techniques that are applied to solve data mining applications is the Artificial Neural Network (ANN). Some significant characteristic of ANNs is fault tolerance, well suited in situations where information is uncertain and noisy. The information processing methodology in ANN differs from the conventional methodologies because employ training by examples to solve any problem instead of a fixed algorithm [5].

There are two kinds of training: supervised training and unsupervised training and unsupervised networks. Some of NN key features are the iterative learning process in which data cases are presented to the network one at a time, every time the weights associated with the input values are adjusted [4]. In the learning phase, the NN process case by case and after all cases are presented, the process often starts over again.

There are two input layers. The first one is the input layer of the network, which the training inputs are applied to it. In addition, the output layer is the second one, which the desired output are compared to it. Also, the output of each element is computed layer by layer until the input layer is reached [6].

Neural Network classifiers satisfy advantageous properties over other methods. Such properties are:

- They are impressive and unlikely to fail as result of the computed weights.
- They are capable to improve their performance based on learning mechanism. This may last even after the training phase has been conducted[7].
- They are able to make amount of predictions greater than training data.
- There are able to reduce error rate and empower the accuracy as soon as the suitable training has been conducted.
- They are unlikely to fail in noisy environment [11,12,13]

IV. DATASET DESCRIPTION

The objective of Cleveland clinic foundation online data source is to serve as a training dataset for Machine Learning algorithms to predict whether a person has heart disease problem or not.

A. Sources of Data:

This dataset is obtained from Cleveland clinic foundation database. It is publicly online available dataset in the UCI machine learning repository which is a repository of databases, domain theories and data generators [8]. It is interested in classifying a person into normal and up normal person concerning heart diseases problems.

B. Data Representation:

The dataset contains 303 instances each one includes 76 attributes, but this experiment uses a subset of 14 of them. In particular, the dataset is usually used by ML researchers. The existence of heart disease problem in the patient indicated by integer values for example (value 0) heart disease does not exist, and (values 1, 2, 3, and 4) heard disease exists. As mentioned above, number of attributes actually used in this experiment is 14 including a class attribute, where no missing value is presented, as shown in Table 1.

Table 1: Data Description.

Attribute	**Data Type**	**Description**
1- Age	Real	Age in year
2- SEX	Binary	1= male 0 = female
3- CP	Normal	Chest pain type: 1= typical angina 2= atypical angina 3= non-anginal pa 4= asymptomatic
4- Trestbps	Real	Resting blood pressure(in mm hg on admission to the hospital)
5- Chol	Real	Serum Cholesterol (mg/dl)
6- FBS	Binary	Fasting Blood Sugar (value 1:>120 mg/dl ;value 0:<120mg/dl)
7- Restecg	Nominal	Resting electrocardiographic results : 0= normal

		1= having ST-T wave abnormality 2= showing probable or define left ventricular hypertrophy by Estes criteria
8- Thalach	Real	Maximum heart rate achieved
9- Exang	Binary	Exercise induced angina (value 1: yes; value 0: no)
10- Oldpeak	Real	Stdepression induced by Exercise relative to rest
11- Slope	Ordered	The slope of the peak Exercise ST segment Value 1 : upsloping Value 2 : flat Value 3 : dowen sloping
12- CA	Real	Number of major vessels colored by floursopy (Value 0-3)
13- THAL	Nominal	Value 3 : normal : Value 6 : fixed defect: Value 7 : reversible defect
14- NUM	Binary	Diagnosis of heart disease Absence (1) or presence (2) of heart disease

V. Feature Selection

Feature Selection, a process of selection a subset of original feature according to creation criteria, is an important and frequently used dimensionality reduction technique for data mining [9]. It reduces the number of feature, removes irrelevant, redundant, or noisy data, and brings the immediate effect for applications, speeding up a data mining algorithm, and improving mining performance such as predictive accuracy and result comprehensibility. They essentially divide into wrappers, filters, and embedded method. Wrappers utilize the learning machine of interest as a block box to score subset of variables as according to their predictive power filters select of subset variables as a pre- processing step, independently of the chosen predictor. Embedded method performs variables selection in the process of training and are usually specific to given learning machines [10]. Usually, there is a systematic way of selecting attributes which includes four phases. In the first phase attribute subset is chosen based on searching algorithm.in the second phase. In the second phase the algorithm is sent for evaluation based on specific criteria. In the third phase, the best suitable subset for evaluation crite.

ria is chosen. In the final phase, the selected subset is validated based on validation subset [11]. The subset that is the best suitable for the evaluation criterion is chosen from all the candidates that have been evaluated after the stopping criterion are met. The table 2 represents the attributes, which are selected.

Table2: Selected Attribute

S. NO	**Attribute**
1	CP
2	Trestbps
3	Thalach
4	Exang
5	Oldpeck
6	CA

VI. Experiment

A. Experiment:

In this experiment, software program is constructed based on back propagation learning model as shown in Figure 1 .The program is evaluated by training and validating the back propagation Neural Network using the Heart Diseases dataset. The back-propagation learning algorithm is provided by momentum and variable learning rate.

B. Data encoding and Normalization:

One of the essential keys to work with neural networks is to understand data encoding and normalization techniques. Usually data normalization is applied to numeric input data while data encoding deals with categorical and binary data. In this experiment, both types are performed on specific attributes. Gaussian normalization is implemented on the age values whilst min-max normalization is implemented on the income values. Values which are normalized by Gaussian normalization technique take values that are typically, between -10.0 and +10.0. At the same time, values that are encoded by min-mix technique take values that are between 0.0 and 1.0. For computing the min-max encoded attributes values, each value of the set values represented based on the minimum and maximum values of the set. In another word, the min-mix normalized value for some value x is (x- min)/ (max – min) very simple. Gaussian normalization is also called standard score normalization. The first step is to compute the mean (average) of the values. The next step is to compute the standard deviation of the values. In general, the Gaussian normalized value for some value x is ((x-min) / stander deviation).

C. Neural Network Computational Model Design:

The neural network model consists of three layers which are input, hiding and output layers. Cleveland clinic foundation database is used for selecting fourteen attributes from 76 attributes, thirteen of them used as an input layer. Each one of them used as a neuron to represent a single input within the input layer of the neural network model. The hidden layer consists of 5 neuron and the output layer with only 1 neuron. The proposed neural network is shown in Fig '1'.

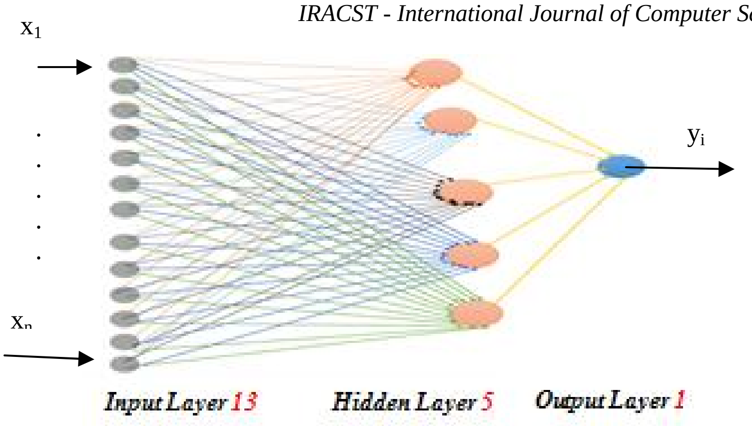

Figure1: The Proposed Heart Disease Diagnose Neural Network

Algorithm 1

1. Read the data set items.
2. Partition the input data set into 80% trained data set and 20% tested data set.
3. Create a back propagation neural network classifier using a learning rate and momentum with 13-input, 5-hidden and 1-output layers.
4. Train the classifier using the trained data set.
5. Compute Weights
6. Display weights
7. Compute the training accuracy.
8. Compute the testing accuracy.

Algorithm 2

```
Train-Classifier(double[,]trainData,max,
  {
      i = 0;
      double[] inputValues ,targetValues ;
      int[] sequence = new int[trainingData.Length];
      for (int j = 0; j < sequence.Length; j++)
      {
         sequence[j] =j;
         while (i < max)
          {
            double mse = MeanSquaredError(trainingData);
            if (mse < smallValue)   break;
            Swap(sequence);
            for (int k = 0; k < trainingData.Length; ++k)
             {
               int idx = sequence[k];
               Copy(trainData[idx],inValues, nOfInput);
               ComputeOutputs(inputValues);
               Copy(trainData[idx],nInput, tValues, 0, nOutput);
               UpdateWeights(tValues,learnRate, momentum);
             }
           i=i+1;
         }
      }
 }
```

Algorithm 2.1

```
Compute-Error(double[,] trainingData)
  {
     double  sumSquaredError , err;
     double[]  inValues, tValues,    outValues;
     for (int i = 0; i < trainData.Length; ++i)
      {
        Copy(trainData[i], xValues, numInput);
        Copy(trainData[i],nInput,tValues,0, nOutput);
        outputValues= his.ComputeOutputs(xValues);.
        for (int j = 0; j < numOutput; ++j)
          {
            err = tValues[j] - yValues[j];
            sumSquaredError += err * err;
          }
      }
      return sumSquaredError / trainingData.Length;
  }
```

Algorithm 2.2

```
Compute-Outputs(double[] xValues
 {
     double[] hSums , oSums ;
     if (inValues.Length != nOfInput)
       throw new Exception("Invalid  Array Length");
     for (int i = 0; i < inValues.Length; ++i)
        this.inputs[i] = inputValues[i];
     while( j = 0; j < numOfHidden)
      {
         for (int i = 0; i < nInput; ++i)
           hSums[j] += this.inputs[i] * this.ihWeights[i][j];
        j=j+1
      }
     for (int i = 0; i < numHidden; ++i).
         hSums[i] += this.hBiases[i];
     for (int i = 0; i < numOfHidden; ++i)
         this.hOutputs[i] = HyperTan(hSums[i]);
     while ( j = 0; j < numOutput)
      {
         for (int i = 0; i < numOfHidden; ++i)
           oSums[j] += hOutputs[i] * hoWeights[i][j];
         j=j+1;
      }
     for (int i = 0; i < numOutput; ++i)
        oSums[i] += oBiases[i];
     softOut = Softmax(oSums);
     Copy(softOut, outputs, softOut.Length);
     retResult = new double[numOutput];
     Copy(this.outputs, retResult, retResult.Length);
     return retResult;
 }
```

Algorithm 2.3

```
Update-Weights (double[] tValues, learnRate, mom)
  {
     if (tValues.Length != numOutput)
          throw new Exception("Invalid target values");
     for (int i = 0; i < numOutput; ++i)
      {
        derivative = (1 - outputs[i]) * outputs[i];
        oGrads[i] = derivative * (targetValues[i] - outputs[i]);
      }

   while( i < numHidden)
     {
       derivative = (1 - hOutputs[i]) * (1 + hOutputs[i]);
       sum = 0.0;
```

```
        for (int j = 0; j < numOutput; ++j)
          {
            x = oGrads[j] * hoWeights[i][j];
            sum += x;
           }
          hGrads[i] = derivative * sum;
          i=i+1;
      }
    while ( i < numInput)
      {
        for (int j = 0; j < numHidden; ++j)
          {
            delta = learnRate * hGrads[j] * inputs[i];
             ihWeights[i][j] += delta;
             ihWeights[i][j]+=mom*ihPrevWeightsDelta[i][j];
             hPrevWeightsDelta[i][j] = delta;
          }
        i=i+1
   }
  while ( j < numHidden)
   {
      delta = learnRate * hGrads[j];
     for (int i = 0; i < numHidden; ++i)
       {
         for (int k = 0; k < numOutput; ++k)
           {
             delta = learnRate * oGrads[k] * hOutputs[i];
              hoWeights[i][k] += delta;
              hoWeights[i][k] += momentum * hoPrevWeightsDelta[i][k];
              hoPrevWeightsDelta[i][k] = delta;
           }
       }
    for (int i = 0; i < numOutput; ++i)
     {
        delta = learnRate * oGrads[i] * 1.0;
        oBiases[i] += delta; oBiases[i] += momentum * oPrevBiasesDelta[i];
        oPrevBiasesDelta[i] = delta; // save
     }
    j=j+1;
  }
 }
```

VII. RESULTS

In this experiment, the proposed neural network algorithm is trained validated and tested using three hundreds and three instances of Cleveland clinic foundation database, where each instance contains fourteen attributes, such attributes are selected from 76 attributes. Some samples of results are organized and tabulated in Table 2 and Table 3.Whilst other results such as optimal weights vector as well as the neural network algorithm accuracy are computed and recorded in Table 4, Table5 and shown in figure 3.

Table 2: Sample of Training Data Set

Id	Thal	Ca	Slope	Oldpeak	Exang	Thalach	Restecg	Fbs	Chol	Trestbp	Cp	Sex	Age	Num
1	-0.1	0	2	0.2	0.3	1	2	0.7	1	0	1	1	3	1
2	-0.8	0	3	0	0.3	0	0	0.4	0	0.2	1	0	3	1
3	-1	0	4	0.6	0.2	0	2	0.6	1	0	2	0	3	1
4	-0.5	0	3	-0.7	0.3	0	2	0.6	0	0.6	1	0	3	1
5	0.3	1	3	-1.2	0.2	0	2	0.7	0	2.5	2	1	7	2
6	1.7	0	3	-1.4	0.3	1	2	0.3	0	0	1	1	3	1

Table 3: Sample of Testing Data Set

Id	THAL	CA	SLOPE	OLDPEA	Exang	Thalach	Restecg	FBS	Chol	Trestbp	Cp	Sex	Age	NUM
1	0.7	0	4	-0.4	0.1	0	0	0.7	0	0	1	0	3	1
2	-1.3	1	4	-1	0.4	0	0	0.9	0	1.2	2	0	3	1
3	0.2	1	3	-0.1	0.2	0	2	0.6	0	0.4	2	1	7	2

Table 4: Neural Network Model Optimal Weights

	1	2	3	4	5	6	7	8	9	10
1	0.005	0.006	0.005	0.001	-0.006	0.001	0.008	-0.001	0.01	-0.005
2	-0.004	-0.001	0.003	-0.001	0.01	-0.009	0.007	0.01	0.004	-0.004
3	0.006	0.007	0.01	-0.009	0.004	0.001	0.009	0.004	0.001	-0.008
4	-0.006	-0.001	-0.004	0.01	0.003	0.005	-0.009	-0.002	-0.003	0.009
5	0	0.004	-0.008	-0.005	0.008	0.006	-0.003	-0.001	-0.007	-0.006
6	-0.002	0.004	0.002	0	-0.006	0.008	0.007	0.005	0.007	0.004
7	0.002	-0.006	0.008	0.008	-0.008	0.007	-0.007	0.003	0.007	-0.006
8	0.01	0	0.003	0.004	0.006	-0.008				

Table 5: Neural Network Algorithm Accuracy.

Testing Data Set %	Accuracy
5	0.98532
10	0.98778
15	0.98714
20	0.985
25	0.98676
30	0.985429
35	0.98625
40	0.987667
Average	**0.9864935**

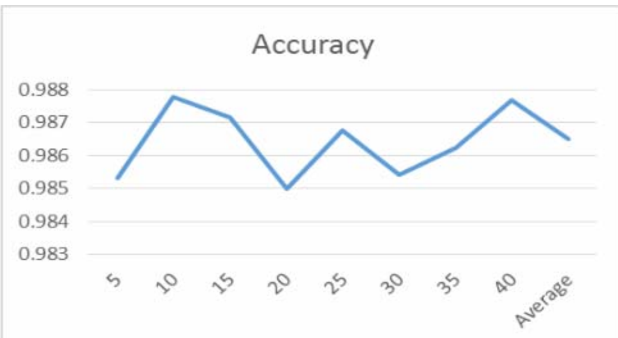

Figure 3: Neural Network Algorithm Accuracy

Table 6: proposed method performance compared to others

	precision	recall	accuracy
proposed method	100	99.13	98.65
previous methods	100	96.86	98.16

Figure 4: proposed method performance compared to previous method

VIII. Analysis of the Result

As indicated in the previous section, a back propagation neural network algorithm is designed and implemented. It is trained, validated, tested using 303 instances of the Heart Diseases dataset. Each instance contains 14 attributes including the output class. The algorithm is trained, tested and validated using different percentages of the dataset. For example, 90% of the dataset is used as a training dataset while 10% of the dataset is used as a testing data set. The most common algorithm performance measures are used and implemented. Such measures are precision, recall, F-measure, training and testing accuracy. On the one hand, the precision is computed by the formula P= (TA/(TA+FA)), where TA is number of people correctly classified as people with heart disease and FA is number of people incorrectly classified as people without heart disease . On the other hand, the recall is computed by the formula R=TA/ (TA+FB), where FB is number of people incorrectly classified as people without heart disease. The F-measure is also computed by a formula that is based on precision (specificity) P and recall (sensitivity) R as F = (2*P*R)/(P+R) whilst the training and testing accuracies are computed by the formula accuracy=(TA+TB)/ (TA+TB+FA+FB), where TB is number of people correctly classified as people not have heart disease. As mentioned above, 10% of the dataset is used as a testing data set and the performance measures are computed and the output results obtained as P=100%, R=99.13%, F=98.65%, as shown in Table 6 as well as in figure 4. Therefore, this classifier outperforms all other previous classifiers [14].

IX. Conclusion

The proposed neural network algorithm is implemented using Cleveland clinic foundation database. After normalizing the dataset and reducing its dimensionality, the algorithm is trained, validated and tested. The output results shows that the algorithm is reliable of heart disease diagnoses based on an optimal weights. Such weight are computed during the training phase and used during the testing phase for making a decision. The algorithm performance is measured and the algorithm accuracy average is recorded as 98.65%. Therefore, the proposed algorithm outperforms than previous algorithms as shown in Table 6 and Figure 4. As a future work, this experiment could be implemented using a big data set and deep neural network[15].

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AUTHORS PROFILE

Dr. Nabeel Taher Alsohybe, presently working as the Deputy Minister of Labor Force in the Republic of Yemen. In addition, he is working as an Assistance Professor in the Faculty of Computer and Information Technology at Sana'a University, Republic of Yemen. He held a PhD in Information Technology Management from Capella University, USA. He completed his master's degree in Telecommunication Systems Management from National University, USA, and earned his B.S. in Computer Science from Sana Jose State University, USA. He worked for seven years for the largest semiconductor company in the world, Intel Corporation, USA where he held several posts.

E-mail: alsohybe@fcit.edu.ye
alsohybe@gmail.com

Dr. Ghaleb H. Al-Gaphari, born in 20/01/1965, Taiz, Republic of Yemen. Professor & Vice-Dean for Academic Affairs, Faculty of Computer and Information Technology, Sana'a University, Yemen.

E-mail: drghalebh@gmail.com