Onset Diabetes Diagnosis Using Artificial Neural Network

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Abstract— Diabetes Mellitus is a chronic, lifelong metabolism disorder that affects the ability of the body system to use the energy found in food. People living with high blood sugar will experience polyuria (frequent urination), which will make them to become increasingly thirsty (polydipsia) and hungry (polyphagia) .The improper management of this disease can lead to complication such as cardiovascular disease, kidney disease, eye disease, nerve disease, pregnancy complication. The database of Pima Indian diabetes has been considered for the diagnosis of the diabetes mellitus. This database comprise of certain attributes which are very adequate for diabetes mellitus diagnosis. The use of this attributes has enhanced the training and test classification of patients, whether diabetes is present or not. In this research work, multilayer feed-forward was created and trained with back-propagation algorithm which classify patient that are tested positive as binary 1 and patient that are tested negative as binary 0.The use of trained neural network gave recognition rate of 82% on test .This recognition rate was later compared to previous researches on diabetes where other types of algorithms was used such as ADAP algorithm, C4.5 algorithm, nearest neighbor with backward sequential selection of feature, EM algorithm. The success rate obtained from multilayer feed-forward trained with back-propagation algorithms is higher than these other algorithms.

Index Terms – Artificial neural network, Back propagation, diagnosis, diabetes.

1 INTRODUCTION

DIABETES is one of the acute diseases that are deadly, disabling and costly all over the world [1]. Diabetes describes metabolic conditions where the body produces inadequate insulin to meet the body need and or their cells do not respond properly to insulin. Insulin is important because it moves glucose or simple sugar, into the cell body from the blood. If insulin is not working properly to move glucose from blood cell, its result in accumulation of glucose in the blood stream. This causes high blood sugar level, which is very toxic to the body system. Also, cells that do not get glucose are starved of the fuel they need.

The early stage of diabetes is called pre-diabetes. It is also known as impaired glucose tolerance, which is a condition where the blood glucose level increase to a level that is higher than the normal range for most people, but it is still low enough to be considered as diabetes. There are three main types of diabetes: (1) Type 1 diabetes (2) Type 2 diabetes (3) Gestational diabetes. Type1 diabetes is an autoimmune disease where the pancreas is unable to produce adequate insulin or produce no insulin at all. Type1 diabetes is common within the people under the age of 20years, it occurs in childhood of a person or young adult. Type 2 diabetes is mostly found among ageing and overweight people. It is known as adult onset diabetes. Type2 diabetes, is often caused by lack of exercises as found among Americans Gestational diabetes is the third types of diabetes, is a condition that women can get, starting from the six months of their pregnancy. About 4% of pregnant women develop gestational diabetes [2].

People with diabetes often stand the risk of developing a number of other serious health problems. Frequent high blood sugar levels can cause serious diseases affecting the heart, blood vessels, eyes, kidney, nerves and teeth. In almost all high income countries diabetes is a leading cause of cardiovascular disease, blindness, kidney failure and lower limb amputation [3].

In 2010, Diabetes was listed as the seventh cause of death in the united state of America with 69,071 death certificates issued. The incidence of diabetes in 2012 was 1.7million new diagnose per year as compared to 1.9million in 2010. About 20800 America under age 20 were estimated to have diagnosed diabetes, approximately 0.25 percent of the population. Presently, diabetes takes more lives than AIDS and breast cancer combined claiming lives every 3minutes [4].

TABLE 1: STATISTICS OF DIABETES POPULATION OF UNITED STATE OF AMERICA [5]

Year	Prevalence	Diagnose	Undiagnosed
2012	29.1million	21.0million	8.1million
2010	25.8million	18.3million	7.0million

From the table1 above, 12.6million out of the total number of 25.8million people living with diabetes in 2010 are women. The risk of heart attack disease which is the most complication of diabetes is more numerous among women than men. Among people with heart attack, women have a lower survival rate and poorer quality of life than men. Women are at a higher risk of blindness from diabetes than men. Women that were undiagnosed of diabetes have longer life expectancy than women with diabetes. The rate at which women of age 25 to 44 years old that are diagnosed of diabetes dead are more than three times the rate of women without diabetes.

All over the world, diabetes is on the rise side and countries are struggling to keep peace. In 2013, the top three countries of people living with diabetes are China, India and United State of America with 98.4million, 65.1million and 24.4million people diagnosed respectively. Presently there are 382million people living with diabetes all over the world. A further 316million with impaired glucose tolerance are at high risk from disease an alarming number that is set to reach 592million by 2035 [6].Common manifestation of diabetes are characterized when either the body doesn't make enough insulin or cannot use its own as well. Medical cases such as hypertension, obesity, sedentary lifestyle are common that contribute to the prevalence of diabetes. Complications of diabetes, such as heart disease, eye complication, kidney disease, nerve damage, foot amputation, dental diseases are caused by diabetes as a result of late diagnose and improper management. Diabetes is a deadly disease, but can be managed by keeping the blood glucose under control as close to normal as possible. For most people with diabetes a healthy range is between 90-130mg/dl before meal and less than 180mg/dl at 1 to 2 hours after meal. Diabetes can be managed through exercise (regular physical activity such as walking up to 30minute daily, dancing and playing table tennis), proper nutrition, adequate taking of prescribed medicine, regular checking of blood sugar and quit smoking.

Presently, many algorithms have been discovered for prediction of biomedical dataset for hidden information including fuzzy logic system, support vector machine, neural network, naive bayes and decision tree. These algorithms have several advantages in terms of fast time in processing and extracting the hidden information in the dataset. Besides, in the reliability of their accuracy. Deng and kasabov used ESOM with 10 fold-cross validation(FC) obtained 78.4% classification [7],[1]. Smith et al proposed neural network ADAP algorithm to build associative models and obtained an accuracy of 76%[8],[1]. Quainla applied C4.5 algorithm and the classification accuracy was 71.1% [9],[1]. Sahan et al used attributes weighted artificial Immune system with 10 fold cross validation method and obtained classification accuracy of 75.87% [10],[1]. All these algorithms have recognition rate that is not good enough for the diagnosis of diabetes mellitus due to its significance in medical field.

In this work we introduce an Artificial neural Network trained with back-propagation to solve the problem of inadequate accuracy in diagnosis of diabetes mellitus. With this method we obtained recognition rate of 82% which shows a better accuracy as compared to the other kinds of algorithms stated above.

The remaining part of the paper is organized as follows: section 2 is on the sample used, section 3 is on the concept of artificial neural network trained with back-propagation, section 4 is the result and comparison with other algorithms result. Section 5 is the conclusion.

2 SAMPLE

2.1 Pima Indian Diabetes Population

The population for this research work is the Pima Indian female who located near Phoenix, Arizona[11]. Pima Indian (Akimel O'odham) of Arizona, in 2006, they have the highest rate of diabetes of any population in the world. They have staggering rates of 70% obesity and hypertension. This population was chosen as a result of high levels of diagnosis for diabetes mellitus. The population has been under continuing study since 1965 by National Institute of diabetes and Digestive and Kidney Disease because of high incidence rate of diabetes [12]. In carrying out the research by National Institute of Digestive and Kidney, each community resident over 5 years of age were asked to undergo a standardized examination every two years which included an oral tolerance test [12]. The diabetes was diagnosed according to the world health Organization standard that if the 2hours post load plasma glucose was at least 200mg/dl (11.1mmol/l) at any survey examination or if the Indian Health Service Hospital serving the community found the glucose concentration of at least 200mg/dl during the course of routine medical care [13]. These datasets were obtained from UCL machine learning. The dataset consist of 768 samples in which 268 are diagnosed as diabetes positive and 500 are diagnosed as diabetes negative.

2.2 Attribute Selection

Eight attributes were considered for the prediction of onset diabetes mellitus in the Pima Indian population. These eight attributes were considered to have high risk of causing the disease in any patient of the age sample considered. The eight attributes made up 768 samples [11]. The eight attributes are stated below:

Attribute 1: Number of times pregnant(NTP)
Attribute 2: Plasma glucose concentration a 2 hour in an oral glucose tolerance test.
Attribute 3: Diastolic blood pressure(mmHg)
Attribute 4: Triceps Skin fold thickness(mm)
Attribute 5: 2 Hour Serum insulin(mu U/ml)
Attribute 6: Body mass index($weight\ in\ kg/height\ in\ m)^2$
Attribute 7: Diabetes Pedigree function
Attribute 8: Age(years)

2.3 Sample Selection

In selecting the dataset used in this research work, several conditions were considered.

- All the patient were female and at least age 21years and above

One examination was considered, the one that reveals a non-diabetic glucose tolerance test and met either of two of the following was chosen per subject.

- Diabetes was diagnosed for the period of five year after examination or
- Diabetes diagnosed after five years later failed to reveal diabetic.

Certain conditions where diabetes was diagnosed within a year of examination were dropped from the model as they were considered easier to predict.

These conditions considered for the selection of samples in this research work gave a result of 768 samples, 268 samples were diagnosed to be diabetes positive and the remaining 500 samples were diagnosed negative of diabetes. In this work, the binary 1 was interpreted as diabetes tested positive and binary 0 as diabetes tested negative.

2.4 Normalization of Sample

In order for the classifier to perform better there is a need for transforming the feature values into homogenous and well behaved values that yield numerical stability. Normalization is a pre-processing stage in which all values are converted to values between 0 and 1. Normalization can be done in two ways. It can be done by considering the amplitude of each attribute and divide each sample by their respective amplitude. It can also be done with respect to their mean and variance of the attribute value. In this paper, the amplitude of each sample attributes were considered and each sample was divided by their respective amplitude which gave the values between 0 and 1. The amplitudes of each sample are listed below from attribute 1 to attribute 8:

TABLE 2: THE AMPLITUDE OF EACH DIABETES ATTRIBUTES [11]

Attributes	Amplitude Value
NTP	17
GTT	199
DPB(mmHg)	122
TSFT(mm)	99
2Hr SI(mu)	846
Body Mass Index(kg/m2)	67.1
DPF	2.42
AGE	81

The dataset before and after normalization are shown in the table below. In this work the first five samples were considered for illustration.

TABLE 3: THE FIRST FIVE SAMPLE BEFORE NORMALIZATION[11].

Attributes					
NTP	6	1	8	1	0
GTT	148	85	183	89	137
DPB	72	66	64	66	40
TSFT	35	29	0	23	35
2Hr SI(mu)	0	0	0	94	168
BMI(kg/m2)	33.6	22.6	23.3	28.1	43
DPF	0.627	0.3510	0.6720	0.1670	2.2880
AGE(yrs)	50	31	32	21	33

TABLE 4: THE FIRST FIVE SAMPLE AFTER NORMALIZATION.

Attributes					
NTP	0.353	0.059	0.471	0.059	0
GTT	0.744	0.427	0.920	0.447	0.67
DPB	0.590	0.541	0.525	0.541	0.33
TSFT	0.354	0.293	0	0.323	0.35
2Hr SI(mu)	0	0	0	0.111	0.20
BMI(Kg/m2)	0.501	0.396	0.347	0.419	0.64
DPF	0.2591	0.1450	0.2777	0.0690	0.9455
AGE(Yrs)	0.617284	0.3827	0.3951	0.26	0.41

The next section shows how back propagation artificial neural network was used for the prediction of the diabetes mellitus.

3 ARTIFICIAL NEURAL NETWORK

Artificial neural network is a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing experiential knowledge and making it available for use [14]. Artificial neural Network refers to the modelling of the brain in two aspects which are functions and structure. Function in terms of the ability of a system to be able to perform the operations of human brain, such as prediction, optimization, controlling, association, thinking, reasoning and so on, structure is in terms of the layers of the neural. The models are composed of many computing elements, usually denoted by neurons; each neuron has a number of input and output [15]. It has a matrix called memory or synaptic weights which connect the input neuron to the hidden neurons and output neurons. A linear combiner is used to produce a single value from all the inputs [15]. The input to the neuron is obtained as the sum of the synaptic weight of the input. The input value is compared to the threshold value associated with the neuron to determine the activation signal of the neuron. This activation signal is then passed through an activation function to produce the output of the neuron. Sigmoid activation function was chosen for this research work due to its soft switching operation and also it helps artificial neural network to represent a more complex problem.

A Back-propagation neural network is a multilayer feed-forward neural network, it considered as one of the simplest and most general method used for supervised training of multilayer neural network. It works in a way that it approximates the non- linear relationship that is between the input and the output. It approximates by adjusting the weight internally. It may also generalize for the input that is not present in the training pattern. The operation of back-

propagation neural network is in two ways which are Feed-forward and back-propagation(feedback).

3.1 Operation of Feedforward Neural Network

Feeding a specified training pattern into the input layer, the input weighted sum to the yth node in the hidden layer is given as

$$T.P_y = \sum W_{xy} X_y + \Theta_y \quad (1)$$

The formula is used to calculate the summation of the input to the neuron. The Θ_y is the weighted value of bias node. The output value of the bias node is 1. This neuron is a false input to each of the neuron present in the hidden layer and output layer. The bias neuron is used to overcome the problem associated with situations where the values of an input pattern are zero because if any input pattern has zero value, the neural network will not be able to train without the bias node.

In order to decide whether a neuron should be fire, the total potential(T.P) is passed on to an appropriate activation function. The result from this activation function determines the neurons output and becomes the input value for the neuron in the next layer connected to it. The typical activation used for this work is sigmoid function due to its soft switching operation.

$$O_y = X_z = \frac{1}{1+e^{-T.P}} \quad (2)$$

Equation 1,2determines the output value for the node z in the output layer

3.2 Backpropagation Operation of Artificial neural Network

Assuming that 0_z is the actual activation value of the output neuron z and the desired output of neuron z is d_z, the difference between the actual and desired output is given as

$$\Delta_z = d_z - 0_z \quad (3)$$

The error signal of the network z can be calculated in the output layer as

$$\delta_z = \Delta_z \, 0_z \, (1- 0_z) \quad (4)$$

$$\delta_z = (d_z - 0_z) \, 0_z \, (1- 0_z) \quad (5)$$

0_z $(1- 0_z)$ is the derivation of a sigmoid function.

The back propagation looks for the minimum value of error function in the weight space using technique known as delta rule. The change in the synaptic weights that connect the input neurons y and output neurons z, using delta, is proportional to the error at neuron z multiplied by the activation neuron y

The equation below is used to modify the synaptic weight $W_{y,z}$ between the output neuron z and neuron y

$$\Delta W_{y,z} = \eta \delta_z X_z \quad (6)$$

$$W_{y,z} = W_{y,z} + \Delta W_{y,z} \quad (7)$$

$\Delta W_{y,z}$ is the change in synaptic weight between neuron y and z, η = learning rate which is a relatively small constant that indicate the relative change in synaptic weights.

To improve the process of updating the synaptic weights, a modification equation 5 is made

$$\Delta W^{m}_{y,z} = \eta \delta_z X_z + \Delta W^{(m-1)}_{y,z} \alpha. \quad (8)$$

In this equation the synaptic weight update during the mth epoch is determined by including a momentum rate that is multiplied to the (m-1)th iteration of $\Delta W_{y,z}$. The momentum rate speeds up the learning process by enhancing the changes in weight to follow the same direction with larger steps. Also, the momentum rate avoids the learning process from settling down at the local minimum.

The figure below shows the typical representation of back propagation neural network.

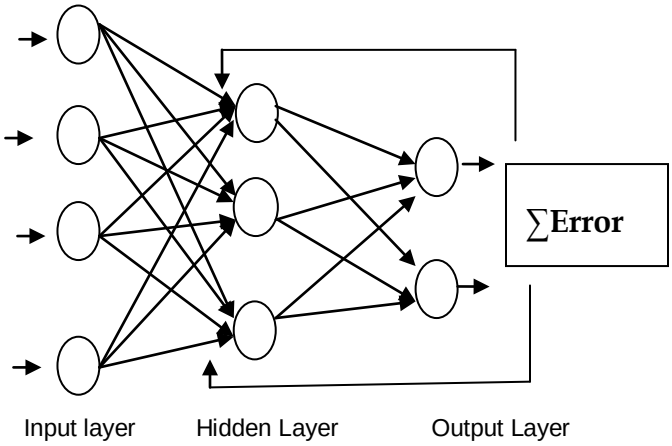

Fig 1: Typical backpropagation neural network**.**

3.3 Design of Artificial Neural Network

The 768 datasets are divided into two(2) set of data, which are the training set and the testing set. The training set comprises of 500 training data and the testing set comprises of 268 testing data. These data were converted into matrix form in order to make use of the neural network tool in Matlab software.

The normalized training datasets and the testing datasetfor the first five samples are illustrated in the table below

TABLE 5: NORMALIZED TRAINING INPUT DATA.

Attributes					
NTP	0.353	0.059	0.471	0.059	0
GTT	0.744	0.427	0.920	0.447	0.67
DPB	0.590	0.541	0.525	0.541	0.33
TSFT	0.354	0.293	0	0.323	0.35
2Hr SI(mu)	0	0	0	0.111	0.20
BMI(Kg/m2)	0.501	0.396	0.347	0.419	0.64
DPF	0.2591	0.1450	0.2777	0.0690	0.9455
AGE(Yrs)	0.617284	0.3827	0.3951	0.26	0.41

TABLE 6: NORMALIZED TEST DATA.

Attributes					
NTP	0.117	0.176	0.3529	0.4118	0.17
GTT	0.587	0.422	0.0	0.4723	0.48
DPB	0.737	0.590	0.5573	0.5246	0.63
TSFT	0.192	0.323	0.4141	0.2525	0.39
2Hr SI(mu)	0.084	0	0	0.0934	0
BMI(Kg/m2)	0.376	0.554	0.5812	0.4963	0.56
DPF	0.129	0.1103	0.3004	0.3049	0.09
AGE(Yrs)	0.259	0.3457	0.5062	0.5062	0.49

At the input layer 8 attributes of 500 training samples are fed into the neural system, therefore we have 8×500 training data which interpreted as 8 rows by 500 columns that was fed into the system. Also, for the testing data we have 8×268 testing data. So far we are dealing with backpropagation algorithm which is a supervised learning there is a need for target which the output of the network will be compared with. The target output have 2 neurons, which are:

1	0

0	1

The target outputs in matrix form are represented as 2× 500 which means 2 rows by 500 columns.

In this research work, artificial neural network was proposed as a multilayer feedforward model which consist of eight (8) input neurons, one hidden layer with 6 hidden neuron which was chosen carefully because too many neurons makes the network over specialized and leading to loss of generalizing capacity. If the hidden layer neurons of the network are not sufficient enough, it will be difficult for the network to understand the behaviour of the pattern. In this research work, varying of the number of hidden layer neurons was experimented with number range between three to seven; six neurons were finally utilized because it offered a better model characteristics. The number of output neurons in this research work are two (2) which determine the class of diabetes mellitus in any patient under consideration whether it tested positive which is interpreted with binary

1	0

or negative, which is interpreted with binary.

0	1

4 RESULT

A backpropagation network with momentum and with learning rate was trained and the neural network can predict the diabetes mellitus given the various input attributes to the network. In this research work, sigmoid transfer function was used in the hidden layer and also in the output layer. The momentum rate used for this research work is 0.66 and the learning rate is 0.33. These two values were chosen during the course of the training. The learning rate determined the speed of the network in learning, i.e the speed at which the network is learning is determined by learning rate provided to the network. When the learning rate is too low, it makes the network to learn very slowly and when it too high, the network might continually jump over the optima weight values and fails to converge. Momentum rate is provided to the network to solve the problem of local minima that is embedded in backpropagation algorithm.

In this research work, the recognition rate of 82% was obtained from training of an artificial neural network with backpropagation which is a good result has compared to the other algorithms such as ADAP algorithm which gave 76%[8],BSS(nearest neighbor with backward sequential selection of feature which gave an accuracy of 67.1[1]. EM algorithm gave a recognition rate of less than 70%[16]. 71.1% was obtained as the accuracy of classification of onset diabetes using C4.5[9].

The table and graphical representation below shows the summary of the result obtained from the training using backpropagation neural network to predict diabetes mellitus and comparison of the backpropagation neural network with other algorithms.

TABLE 7: PERFORMANCE TABLE FOR THE ARTIFICIAL NEURAL NETWORK TRAINED WITH BACKPROPAGATION.

No of training samples	500	No of Input neuron	8
No of testing sample	268	No of hidden neuron	6
No of correct recognition	228	No of output neuron	2
Recognition rate	82%	Epoch	2000
Learning rate	0.33	Time	30sec
Momentum	0.66	Performance	0.21095

TABLE8: COMPARISON OF THE BPNN WITH OTHER ALGORITHMS

BSS	67.1%
EM algorithm	<70%
KNN	72%
C4.5	71.1%
BPNN	82%

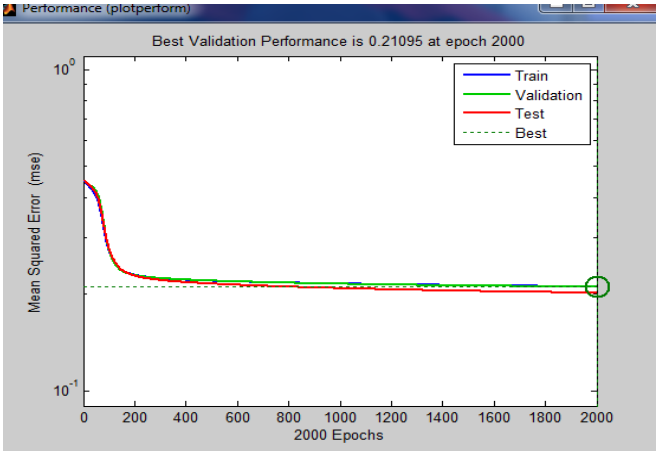

Fig 2: Graph of Minimum Square Error against number of iterations.

5 CONCLUSION

Diabetes mellitus has been one of the challenging diseases which its classification is significant in medical field. The best classification of this disease has been the ultimate goal of researchers, medical doctor and patient in order to avoid a situation where a patient that is diabetes negative is diagnosed

has been positive, this may result in wrong prescription of drug to such patient and also it will be more deadly for a patient that is diabetes positive to be diagnosed as diabetes negative.

Early diagnoses of this disease has proof that the patient that is classified as positive can manage the disease in terms of taking the necessary drug prescribed by the doctor, undergoing required exercises and eating the required food prescribed by the nutritionist, as compare to a case where the patient was ignorance or a delay in diagnoses which may lead to complications such as cardiovascular disease which may result into untimely death, Kidney disease, nerve disease, eye disease which may cause blindness of eye.

Several algorithms have been used for the prediction of onset diabetes mellitus which their result is not good enough because of its significant in the field. But, this research work, as shown, that artificial neural network trained with backpropagation has a higher success on onset diabetes diagnosis. Artificial neural network trained with backpropagation (BPNN) gave 82% recognition which outperform recognition rate obtained from other algorithm.

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