A Neural Network Based Expert System for the Diagnosis of Diabetes Mellitus

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Abstract. Diabetes is a disease in which the blood glucose, or blood sugar levels in the body are too high. The damage caused by diabetes can be very severe and even more pronounced in pregnant women due to the tendency of transmitting the hereditary disease to the next generation. Expert systems are now used in medical diagnosis of diseases in patients so as to detect the ailment and help in providing a solution to it. This research developed and trained a neural network model for the diagnosis of diabetes mellitus in pregnant women. The model is a four-layer feed forward network, trained using back-propagation and Bayesian Regulation algorithm. The input layer has 8 neurons, two hidden layers have 10 neurons each, and the output layer has one neuron which is the diagnosis result. The developed model was also incorporated into a web-based application to facilitate its use. Validation by regression shows that the trained network is over 92% accurate.

Keywords: Expert system · Diabetes diagnosis · Neural network
Back propagation algorithm

1 Introduction

Diabetes is a disease that occurs as a result of the glucose levels being too high due to the absence of, or inadequate amount of insulin in the body. It is a defect in the body's ability to convert glucose (sugar) to energy. Glucose is the main source of fuel for our body. Diabetes develops when the pancreas fails to produce sufficient quantities of insulin (Type 1 diabetes) or the insulin produced is defective and cannot move glucose into the cells (Type 2 diabetes) [1]. Either insulin is not produced in sufficient quantities or the insulin produced is defective and cannot move the glucose into the cells.

The damage that is caused by diabetes can be very severe. It can cause damage to the eyes (blindness), the kidney (kidney failure), the heart (heart attacks), stroke and even lead to amputation [2]. The IDF (International Diabetes Foundation) has stated that 415 million people have diabetes in the world and more than 14 million people have it in Africa. Out of this 14 million Africans, a whopping 1.56 million cases are from Nigeria alone where 1.9% of the adult population has been diagnosed of the same.

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Early detection however, can help to bring it under control. The importance of early detection cannot be over emphasized in the treatment of diabetes. It is an important step in the process of recovery for the patient [1]. An early detection of the diabetes mellitus will help in ensuring that the symptoms do not intensify to the level of the severe cases.

The healthcare sector has seen the rise of some of the most promising and groundbreaking startups in the technology world. These innovations have primarily been driven by the advent of software and mobility of digital devices allowing the health sector to automate many of the pen and paper-based operations and processes that currently slow down service delivery. More recently, we're seeing software become far more intelligent and independent. These new capabilities (studied under the banner of artificial intelligence and machine learning) are accelerating the pace of innovation in healthcare. Thus far, the applications of artificial intelligence in health-care have enabled the industry to take on some of its biggest challenges in these areas which include pharmacy, genetics and diagnosis of diseases. Diabetes diagnosis in particular is a complicated process that involves a variety of factors, from the texture of a patient's skin to the amount of sugar that he or she consumes in a day. For as far back as 2,000 years, medicine has used the method of detecting symptoms, where a patient's disease is diagnosed in view of the symptoms that can be spotted (For example, if you have a fever and running nose, you probably have the flu). Be that as it may, the timing of the display of detectable symptoms is too late, especially for deadly ailments like diabetes, cancer and Alzheimer's disease. With artificial intelligence, there is hope that the diseases can be detected well in advance, which will increase the probability of survival (sometimes by up to 90%) [3].

This research is therefore aimed at developing such a system for the diagnosis of diabetes mellitus by leveraging on a neural network based expert system. The remainder of this work is arranged as follows: Sect. 2 discusses the literature review, Sect. 3 explains the methodology while Sect. 4 shows the implementation. The final section concludes the work.

2 Literature Review

The greatest health threats in developed countries are heart disease, cancer, and diabetes [4]. Diabetes particularly is a prevalent disease that has been rising at an increasing rate in a lot of third world countries, including Nigeria. In extreme cases, it is a major cause of severe diseases such as blindness, kidney failure, heart attacks, stroke. In 2012 about 1.5 million deaths were recorded because of diabetes mellitus and another 2.2 million deaths were caused by high blood glucose. WHO projects that diabetes will be the 7th leading cause of death in 2030.

The burden of diabetes on pregnant women is even unique because it can affect both the mother and the unborn child and cause complications in child birth. Diabetes in pregnancy may be neglected due to poor awareness, finances or substandard medical care. This subsequently increases the risk of their offspring getting diabetes, particularly if the diabetes in pregnancy is uncontrolled and continues a disturbing trend of diabetes from generation to generation [5]. There is also the issue of lack of adequate medical personnel and facilities specially to compile the necessary tests required to diagnose the disease. All these make for a compelling case as to why a system that can aid the pre-diagnosis of diabetes is needed. The field of artificial intelligence has come to the rescue in this regard, as several expert systems have been built to salvage similar situations.

An expert system can be defined as a program designed to solve problems at a level comparable to that of a human expert in a given domain [6]. It can also be defined as a software system that is able to solve specific complex problems at the level of human experts by the manipulation of accumulated information from the experts following rules that have been set down by the knowledge engineer. The aim of an expert system is to resolve specific issues that would otherwise require these experts through the intelligence gained from them [7]. Expert systems exist in numerous domains, from medical diagnosis to investment analysis and from counselling to production control. Most expert systems have essential components in common [7], which are:

1. The knowledge-base: which stores the knowledge and expertise gathered from experts in that area; information that makes them experts in that category.
2. The Inference Engine: carries out the reasoning through which the expert system reaches a solution.
3. A User Interface: which is the medium through which the expert system can interact with the user. This is done through various methods like dialogue boxes, command prompts etc.
4. Explanation Facilities: This is required to give an explanation as to how and why a particular decision or solution was derived.
5. Working Memory: The working memory for an expert system consists of both facts imputed from questions asked by the expert system to the user, and facts that are deduced by the system. Precise information on a particular problem is represented as case facts and imputed in the expert system's "working memory".

As medical information systems in modern hospitals and medical institutions become larger, it causes great difficulties in extracting useful information for decision support. The manual method of analyzing data has become inefficient, making newer and better methods of computer based analysis essential. It has been proven that the benefits of introducing artificial intelligence into medical analysis are to increase diagnostic accuracy, to reduce costs and to reduce human resources [7]. Artificial Neural Networks (ANN) is currently the next promising area of interest. Already it could successfully apply to various areas of medicine such as diagnostic systems, bio-chemical analysis, image analysis and drug development.

It is one of the techniques used to implement expert systems; a supervisory learning algorithm that models based on the human brain and nervous system. It is composed of artificial neurons and interconnections [8, 14]. Every interconnection (link) has a weight associated with it which determines the strength and the sign of the connection [9].

A neural network consists of layers of similar neurons. It consists of at least an input layer, an output layer and one or more hidden layers. There are several network architectures, with the Feed-forward being the most common because of its versatility. The term feed-forward describes how this neural network processes and recalls patterns. In a feed-forward neural network, each layer of the neural network contains connections to the next layer, the connections extend forward from the input layer to the hidden layer, but no connections move backwards.

The feed-forward neural network can be trained with a variety of techniques from the broad category of back-propagation algorithms, a form of supervised training to optimization algorithms.

2.1 Related Works

[10] made a system that used data mining techniques such as Bayesian Regularization Algorithm, J48 and Radial Basis Function Artificial Neural Networks for diagnosing diabetes type 2. They took advantage of a data set with 768 data samples, 230 of them selected for test phase. Bayesian Regularization Algorithm with 76.95% accuracy outperformed J48 and RBF with 76.52% and 74.34% accuracies, respectively.

Another system that made use of the back-propagation multi-layer artificial neural networks for identifying diabetes mellitus type 2 was done by [11]. Back-propagation is a supervised learning algorithm that works by correcting errors as it "trains" itself to get better. It models the computed output value with the real or expected value and tries to modify the weights according to the calculated error such that the error value keeps reducing till it reaches as little as possible. Sigmoid function was used to train back-propagation and the Pima-Indian database was used. The data set contains 768 data samples, 568 of which were used for training and 268 as testing set. The network developed contained 8 input layer neurons, 6 hidden layer neurons and 2 output layer neurons. Note that the input layer neurons are the eight features which were used in the data set. After 2,000 rounds it reached 82% accuracy.

[12] also made use of the multilayer perceptron (MLP) artificial neural networks for identifying diabetes type 2. In this paper, MLP model includes one input layer with feature of Pima Indians Diabetes, hidden layer with certain neurons and an output layer which has the responsibility of diagnosis. About 20% of data are used as training set, 60% as testing set and finally 20% are used as application set. Time and number of neurons in hidden layer of MLP model are two important parameters. Finally, highest diagnosis accuracy in training phase using MLP model with maximum time and minimum number of neurons in hidden layer in comparing with same times and neuron numbers was 97.61%.

Another set of authors used a dataset with 250 data samples for diagnosing diabetes disease [6]. Each of these 250 data samples consist of 27 features. These features include blood pressure, creatine, pH urine, and fasting blood sugar. Also, the average age of patients in their dataset is between 25 and 78 years. Multi-layer feed-forward artificial neural networks with back- propagation are used for diagnosis. Three training functions namely BFGS Quasi-Newton, Bayesian Regulation and Levenberg-Marquardt are applied in back-propagation algorithm. Finally, back-propagation with Bayesian Regulation function achieved 88.8% of diagnosing accuracy which performed better than BFGS Quasi-Newton and Levenberg-Marquardt functions. Furthermore, data mining techniques with Pima Indians Diabetes dataset is used for identifying diabetes. The applied data mining techniques include SVM, KNN, C4.5 and artificial neural networks with input, hidden and output layers. Finally, artificial neural networks have a higher diagnosing accuracy compared to other data mining techniques [6].

In yet another case, authors use general regression neural networks and Pima Indians Diabetes for identifying type-2 diabetes [13]. A general regression neural network model in this paper is assumed to be a four-layer model; -ne input layer with 8 features from Pima Indians Diabetes, two layers which have 32 and 16 neurons, respectively. Finally, output layer has one neuron. This neuron determines if a person is positive or not. It is used for classification of Pima Indians Diabetes dataset into healthy and patient classes. The above-mentioned dataset with 576 data sample as training set and 192 data set as testing set is used for training and testing processes. The accuracy rate achieved for training and testing phases are 82.99% and 80.21%, respectively. Training phase for diagnosing diabetes type 2 obtained a higher value of accuracy compared to other works studied in this paper [13].

The aim of work however, is to develop a functional neural network based expert system to diagnose diabetes mellitus in women.

3 Methodology

A 4-layer Artificial Neural Network was designed and trained using the Back-propagation method and the Bayesian Regulation (BR) Algorithm. The back propagation learning algorithm works by correcting errors as it "trains" itself to have less errors. It models the computed output value with the expected value (1 or 0) since it has binary output, 1 for true and 0 for false. The BR algorithm was used additionally to avoid over fitting the data set. The dataset was gathered from a medical database called the Pima Indian Database set. It contains 768 rows of data. The individual used were tested on Blood Pressure, Triceps Skin Thickness, Insulin, Body Mass Index, Diabetes Pedigree Function, and age. 500 people tested positive and 268 tested negative to make a total of 768 people.

The Matlab software application was used for the training. Training is the process of modifying the network using a learning mode in which an input is presented to the network along with the desired output. The weights are then adjusted so that the network attempts to produce the desired output. The data set was divided for training, testing and validation. 70% for training, 15% for testing and 15% for validation. The data is trained until it can form a single and accurate output as displayed in the regression graphs in Fig. 2.

3.1 Neural Network Design

The neural network model consists of four layers of neurons as shown in Fig. 1. The input layer with eight (8) neurons, the two hidden layers with ten (10) neurons each, and the output layer with a single neuron.

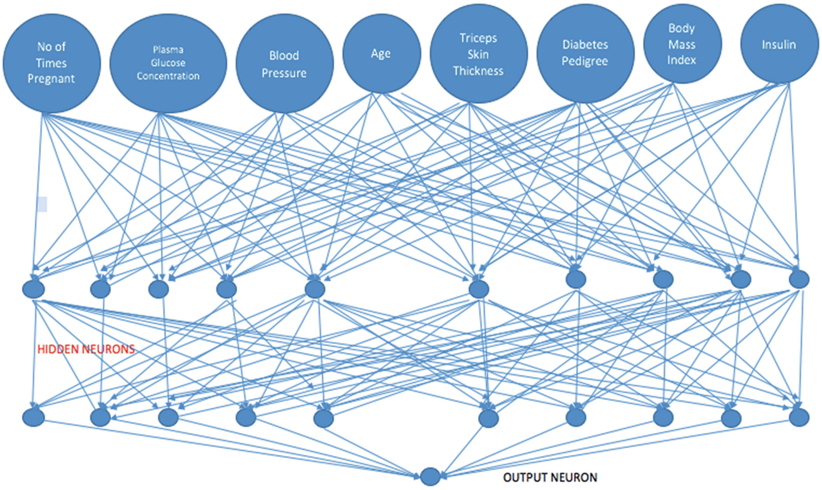

Fig. 1. The neural network model

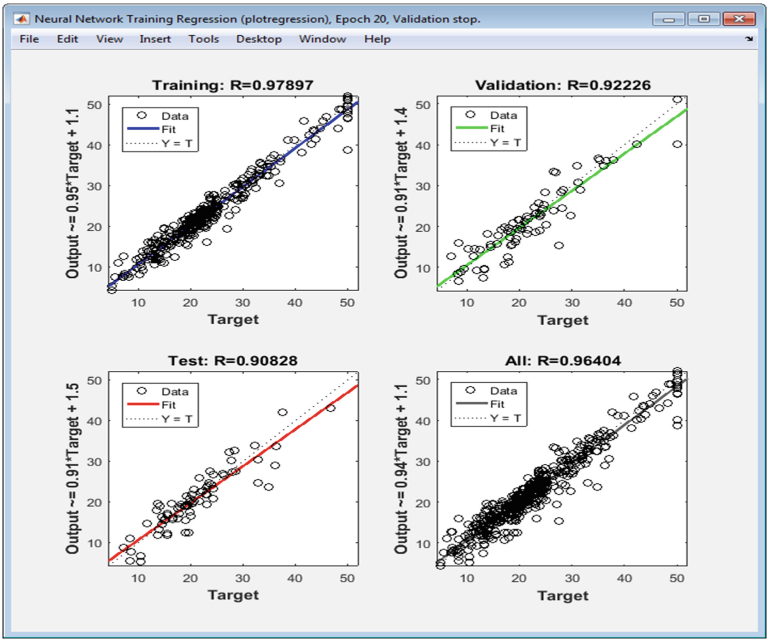

Fig. 2. The regression graph

The Input Layer

This layer consists of eight input neurons which represent the eight inputs that are needed by the system to initiate the diagnosis. These eight inputs represent:

1. The number of times the user has been pregnant;
2. The user's plasma glucose concentration: This is a fasting test which involves abstinence from food and water for a period of 8–10 h before a blood sample is taken. Normal quantity is anything below (6.1 mmol/l) or (101 mg/dl) while concerning quantity is between (6.1 and 6.9 mmol/l) or (111 mg/dl and 125 mg/dl) and diabetic is above (7.0 mmol/l) or (126 mg/dl);
3. The blood pressure of the user (mm Hg);
4. The triceps skin thickness which is at an average of 12 mm for women and 23 mm for the men;
5. Insulin (mu U/ml);
6. Body mass index (weight in kg/(height in m) ^2);
7. Diabetes pedigree function;
8. Age.

The Hidden Layer

Two hidden layers were used with ten neurons each. The hidden neurons have two important characteristics. First, they only receive input from other neurons, such as input or other hidden neurons. Second, they only output to other neurons, such as output or other hidden neurons. Hidden neurons help the neural network understand the input, and they form the output. However, they are not directly connected to the incoming data or to the eventual output.

The Output Layer

There is only one output layer with one neuron which represents the diagnosis result; The neuron that contains the result of the user in decimal form. If the result is 0.5 or greater then, the user has diabetes mellitus while if the result is lower than 0.5 then the user does not have diabetes.

4 Implementation

After the design of the neural network model, a web-based application was built to use the model, so that patients can easily enter their details and get a diagnosis of whether they have the potential to be diagnosed of diabetes or not.

The Training Code was rewritten in JavaScript with Node.js. JavaScript is an incredibly popular programming language, mostly seen in web browsers but gaining popularity in other contexts. On web pages it adds interactivity, from simple animation effects to form validation to full-blown single-page applications.

The interfaces which are the various GUI which the users interact with and also the program modules -operations that can be carried out were also programmed.

The screen shots of the developed system are shown in Figs. 3 and 4. Figure 3 is the home page which is displayed to authorized users of the system after they have logged in. From the home page a user can move on the diagnosis page as shown in

Fig. 4. In this page, the user enters required details needed by the input layer for accurate diagnosis.

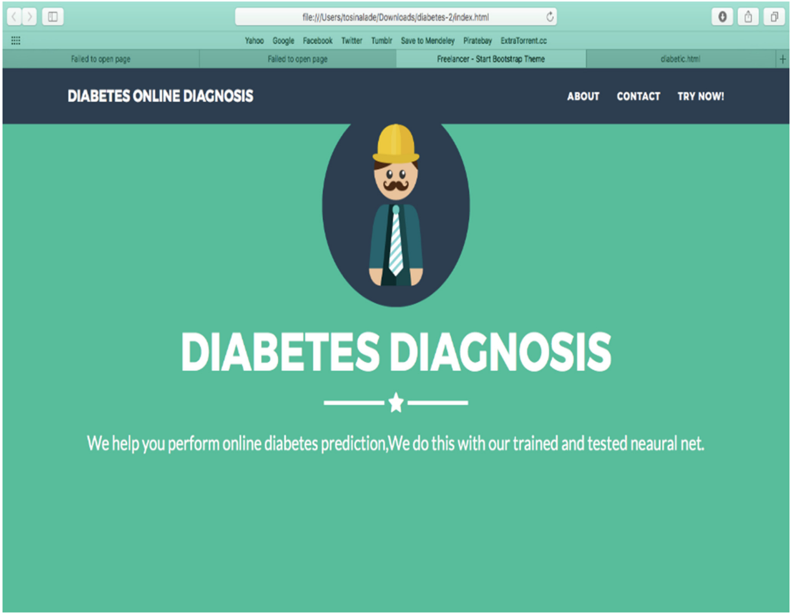

Fig. 3. Homepage of the diagnosis system

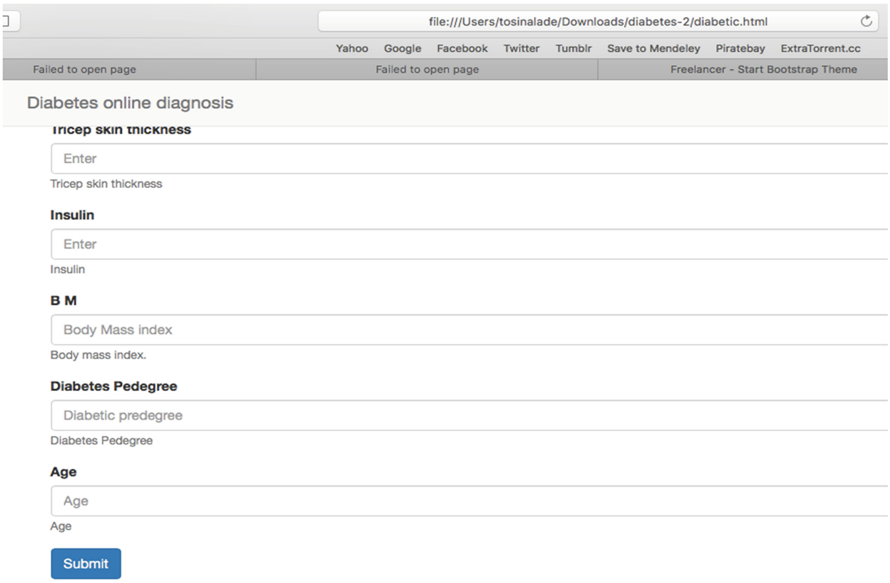

Fig. 4. Diagnosis page

5 Conclusion

This research has developed a neural network model to help in the diagnosis of pregnant women whether they have diabetes or not. The developed model has also been incorporated into a web based application for easy accessibility. As such, health workers or patients at remote locations can access the system, enter patient data in real time and communicate the diagnosis without having to be around the patient.

Some recommendations for its advancement include a Mobile Platform. The system is on a web-based platform at the moment but it would be more beneficial if the system can be based on mobile platforms where there can be offline access on phones, and other devices.

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References

1. ASPE: Diabetes: A National Plan for Action. The Importance of Early Diabetes Detection. https://aspe.hhs.gov/report/diabetes-national-plan-action/importance-early-diabetes-detection
2. U.S. National Library of Medicine: Medlineplus - Health Topic - Diabetes. https://medlineplus.gov/diabetes.html
3. Gupta, M., Mohammad, Q.: Advances in AI and ML are reshaping healthcare. https://techcrunch.com/2017/03/16/advances-in-ai-and-ml-are-reshaping-healthcare/
4. CIA: CIA. Long-term Global Demographic Trends: Reshaping the Geopolitical Landscape, vol. 5 (2011)
5. Thomas, N.: A Practical Guide to Diabetes Mellitus. Jaypee Brothers Medical Publishers Limited, Tamil Nadu (2016)
6. Kumar, S., Kumaravel, A.: Diabetes diagnosis using artificial neural network. Int. J. Eng. Sci. Res. Technol. **2**(6), 1642–1644 (2013)
7. Negnevitsky, M.: Artificial Intelligence: A Guide to Intelligent Systems. Pearson Education, Harlow (2005)
8. Munakata, T.: Fundamentals of the New Artificial Intelligence. Springer, London (2008)
9. Russell, S., Norvig, P.: Artificial Intelligence. A Modern Approach, 3rd edn. Prentice Hall, Upper Saddle River (2010)
10. Sa'di, S., Maleki, A., Hashemi, R., Panbechi, Z., Chalabi, K.: Comparison of data mining algorithms in the diagnosis of type II diabetes. Int. J. Comput. Sci. Appl. **5**, 1–12 (2015)
11. Olaniyi, E., Khashman, A.: Onset diabetes diagnosis using artificial neural network. Int. J. Sci. Eng. Res. **5**, 754 (2014)
12. Al-Mufad, N., Al-Hagery, M.A.: Using prediction methods in data mining for diabetes diagnosis, vol. 1 (2014)
13. Kayaer, K., Yildirim, T.: Medical diagnosis on Pima Indian diabetes using general regression neural networks, vol. 6 (2003)
14. Lino, A., Rocha, Á., Sizo, A.: Virtual teaching and learning environments: automatic evaluation with artificial neural networks. Clust. Comput., 1–11 (2017)