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Harnessing Soft Computation for Diabetes Care: A Computational Approach to Metabolic Disorders

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Abstract

Diabetes mellitus (DM), commonly known only as diabetes, is a group of metabolic disorders characterized by high blood sugar levels over a prolonged period. Symptoms often include frequent urination, increased thirst and increased appetite. If left untreated, diabetes can cause many health complications. Acute complications can include diabetic ketoacidosis, hyperglycemic hyperosmolar state, or death. Serious long-term complications include cardiovascular disease, stroke, chronic kidney disease, foot ulcers, nerve damage, eye damage and cognitive impairment .

Soft computation refers to a set of new computational methods in computer science, artificial intelligence, machine learning, and many other applied fields. In all these fields, the study, modelling and analysis of very complex phenomena is needed, and accurate scientific methods have not been able to solve them easily, analytically and thoroughly in the past. Soft calculations are devoted to human beings compared to the hard calculations and measures taken by their mind in order to resolve problems, while the hard methods arise from nature and the way the machine behaves .

Keywords: Diabetes mellitus, Soft computation, Computational approach, Metabolic disorders, Blood sugar management

Introduction :

Diabetes, commonly known as DM or sugar, is a group of metabolic disorders characterized by high blood sugar levels over an extended period. The most common signs of diabetes include frequent urination, increased thirst, and heightened appetite. If left untreated, diabetes can lead to various complications, such as diabetic ketoacidosis, hyperosmolar hyperglycemic state, and even death. Long-term complications include cardiovascular diseases, cerebral strokes, chronic kidney disease, leg ulcers, nerve damage, eye damage, and cognitive disorders .

Soft computing refers to a collection of novel computing methods utilized in computer science, artificial intelligence, machine learning, and other applied fields. These fields often involve studying, modeling, and analyzing highly complex phenomena that cannot be easily, analytically, and completely solved using traditional scientific methods. Unlike hard computing, which relies on nature and machine behavior, soft computing is dedicated to understanding human thought

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processes and problem-solving approaches. Notable branches of soft computing include fuzzy logic, artificial neural networks, and genetic algorithms .
Artificial neural networks, specifically, are information processing systems that share similarities with natural neural networks. They are mathematical models inspired by neurobiology and human cognition. In this research, we will focus on utilizing neural networks for disease diagnosis.

Neural Network

One of the biggest unknowns of mankind at present is the way of his perception. We still don't know how our brain thinks, recognizes images, etc. We only know that by learning a subject, changes occur in a part of the brain and its neurons. So, our brain, which is the most complex system, is still an unknown black box. We know that this black box produces the right output with training and practice for its inputs. Artificial neural networks also try to simulate brain neurons to a small extent. Artificial neural networks arise from the mathematically simulated connection of artificial neurons. The number of these neurons and how they are connected can be very variable. In this way, artificial neural networks act like a black box that responds appropriately to their inputs. The history of artificial neural networks is full of creative people from different scientific fields, each of whom worked for decades to develop the concepts that we currently have. Some of the early activities in the field of neural networks took place in the late19 19th and early 20th centuries. Scientists in various scientific fields, such as physics, psychology, and neurophysiology, carry out these activities . Hermann von Helmholtz, Ernst Mach, and Ivan Pavlov, There have been .
In these early activities, theories of learning, vision, and conditioning were strengthened, and of course, there was no discussion about mathematical models of neural operations. The modern view of neural networks in the1940 s started with the work of Warren McCulloch and Walter Pitts Began. They showed that a network of neurons can calculate any mathematical or logical function. Their activity in this field can be considered as the origin of the science of artificial neural networks. The McClatchy and Pitts Way by Donald Hebb continued. He proposed a mechanism for learning in living neurons. The first practical application In these years, The 1950s, of living neural networks was formed in the late.
Frank Rosenblatt invented perceptron networks and their learning rules. While building a perceptron network, Rosenblatt and his colleagues proved that these networks can recognize patterns. At the same time, Bernard Vidro and Ted Hoff proposed a new learning algorithm became. While building a perceptron network, Rosenblatt and his colleagues proved that these networks can recognize patterns. At the same time, Bernard Vidro and Ted Hoff proposed a new learning algorithm and used it to train an adaptive linear Teo and Cohen, 1972 neural network. James Anderson independently developed a new neural network that could act as a memory. Stephen Grossberg was also very active in this period and did extensive research in the field of self-organizing networks. The interest was interrupted due to the lack of new 60s in neural networks in the late days of both these ideas and the lack of powerful computers. During the 1980s, obstacles were removed, and the research in the field of neural networks got a new life. In the last ten years, thousands of articles have been written in this field, and neural networks have become very useful every day; a new whisper is heard about a new theory with a new application .

- Definition of artificial neural networks

Soft computing refers to a set of new computing methods in computer science, artificial intelligence, machine learning, and many other applied fields. In all these fields, there is a need to study, model, and analyze very complex phenomena, which precise scientific methods have not been successful in solving easily, analytically, and completely in the past. Compared to hard calculations, soft calculations are dedicated to humans and the measures adopted by their minds in order to solve problems, while hard methods are derived from nature and the way machines behave .

Fuzzy logic, artificial neural networks, and genetic algorithms can be mentioned as the most important branches of soft computing. The artificial neural network is an information processing system that has features that are similar to natural neural networks. Generalized artificial neural networks of the mathematical model of human recognition based on neurobiology. These networks are based on the following assumptions

-1 Information processing takes place in simple components with a large number of neurons

-2 Signals are transmitted between the neurons of the network through their links or connections

-3 Each link has its weight in the common neural networks. The signals transmitted from that link are multiplied

-4 Each neuron has an activation function (usually non-linear) on its inputs, which is a weighted sum of the signals. is input, it applies to produce its output signal

.express an artificial neural network with the following characteristics

• Features of artificial neural networks

Despite the fact that artificial neural networks are not comparable to the natural nervous system, they have characteristics that make them useful in some applications, such as pattern separation, robotics, control, and generally wherever learning and linear or non-linear mapping are required. If it is linear, they prefer it. These features are as follows:

• Learning Ability

Extracting analytical results from a non-linear mapping specified by several examples is not a simple task. Because the neuron is a nonlinear device, a neural network formed by the community of these neurons will also be a completely complex and non-linear system. In addition, the non-linear property of the processing elements is distributed throughout the network .

Implementation of these results with a normal algorithm without learning capability requires great care and precision. In such a case, a system that can extract this relationship itself seems very useful. Especially, adding possible examples in the future to a system with learning capability is much easier than doing it in a system without such capability because, in the latter system, adding a new example means replacing all previously done work

:The steps are

-1 The pattern of connections between different neurons of that network is called the structure or architecture of the network

-2 The method of determining the weights on the network links ,

.which is called the teaching or learning algorithm 3- Network activation function that each neuron applies to its inputs .

Learning capability means the ability to adjust the parameters of the network (synaptic weights) over time when the environment of the network changes and the network experiences new conditions, with the aim that if the network is trained for a specific situation and a small change in its environmental conditions (state special) occurred, the network can also be useful with brief training for new conditions .

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Another thing is that information in neural networks is stored in synapses, and each neuron in the network is potentially affected by the entire activity of other neurons. As a result, the information is not of a separate type but is affected by the entire network. Dispersion of information processing information in the form of text What the network learns (information or knowledge) is hidden in the synaptic weights. There is no one-to-one relationship between inputs and synaptic weights. It can be said that each synaptic weight is related to all inputs, but it is not related to any of them individually and separately. In other words, each neuron in the network is affected by the entire activity of other neurons. As a result, information is processed as text by neural networks. Based on this, if part of the network cells are removed or have a wrong function, there is still a possibility of reaching the correct answer. Although this probability has decreased for all inputs, it has not disappeared for any of them.

•Generalization ability

After the initial examples have been trained to the network, the network can be confronted with an untrained input and provide an appropriate output. This output is obtained based on the generalization mechanism, which is nothing but the interpolation process. In clearer words, the network learns the function, learns the algorithm, or obtains a suitable analytical relation for a number of points in space. And processing standards. When a neural network is implemented in hardware form, the cells that are placed in an alignment can simultaneously respond to the inputs of that alignment. This feature increases processing speed. In fact, in such a system, the overall task of processing is distributed among smaller processors independently of each other.

- resistant to be

In a neural network, each cell acts independently, and the overall behaviour of the network is the result of the local behaviour of several cells. This feature keeps local errors away from the final output. In other words, cells correct each other's local errors in a cooperative process .This feature increases the robustness (tolerance of errors) in the system.

The disadvantage of artificial neural networks in forecasting and designing networks is that the nervous artificial process is very complicated. You are in a place where no systematic method exists for this purpose, and mainly, the trial and error method is used. Process learning, processes time stuck, and time on is why that .

Most connections for variables must be continuously changed. Without these repeated retraining, the accuracy of the network will decrease. Network hi nervous artificial single when may can results are you well provide do that to are you well education seen to be and this requires the preparation of a comprehensive and complete training set with high accuracy. On contrary section before, question important other possibility occurrence education over from limit at network hi nervous artificial is. This excessive training can have many reasons, which cause a decrease in accuracy in the networks. He gets nervous. Most iterative methods are criticized in terms of freedom in modeling, thus building outputs. It is not easy to be sure of such iterative methods such as neural networks. In general, all defects or at least most of them, are related to the black-box nature of artificial neural networks .

Different steps in neural networks

In modeling with artificial neural networks, there are three main stages: training, development, and implementation. Below is a brief description of each step. Training: In this step, the network learns to recognize the existing pattern among the data. In each network, a set of rules is used to train the data.

Generalization: The outputs of a trained network are called generalizations for the inputs that were not in the training phase. In other words, an acceptable output for an input that was not present in the network during the training phase. Implementation: Neural networks are trained to perform various tasks, including approximation of functions. Using the neural network for the purpose for which it was designed and trained is called implementation.

Different methods of network learning

According to the training method, artificial neural networks can be divided into three categories: reinforcement learning, supervised learning, and unsupervised learning.

- Supervised learning

Supervised learning, also known as teacher-directed learning in scientific literature, can be considered a process in which a teacher works to check the correctness of a system, display the desired response on its behalf, and confirm the correctness of the response. System and display its error value. The teacher knows about the environment around the system, and this knowledge is introduced to the system in the form of input and output data. However, the environment for the neural network is dumb, and the teacher can provide the neural network with the correct answer for this training vector by using a training vector. The correct answer determines the optimization done by the neural network. The effective network weights and biases are set from a combination of the training vector and the specified error. After these adjustments are made, moment by moment, they try to force the neural network to follow its teacher in a statistically favorable situation. When the teacher's knowledge is available to the network after the completion of the training, the teacher will Be able to imagine the connection between the network and its surroundings. Learning is based on reducing the error value of a closed-loop or feedback system, but the unknown learning environment under supervision is not a loop, and the system performance is calculated based on the sum of squared errors on test data, which is like a multidimensional average error level. It can be seen in all input and output data. Each operation of the system is displayed as a point on the mentioned surface under the supervision of the teacher. In a system whose performance improves over time and is therefore taught by the teacher, the correct point must successfully move towards a global or local minimum point from the abovementioned level. One The network with supervised learning will be able to perform the desired action by using the gradient information and its gradient slope. The gradient of a surface is a vector for every point, and all points are in the direction of the greatest decreasing slope .

- Reinforcement learning

This learning method is based on the principle that while there is a teacher who specifies the desired behaviour of the network, there is a qualitative expression of the desirability or non-desirability of the behaviour of the network. Therefore, this state is considered between two learning rates with supervision and without supervision .

Reinforcement learning is implemented in such a way that a performance criterion known as the reinforcement signal is maximized. In other words, if the network changes its weights and biases so that it reaches a desired state, then the desire of the network to produce that particular action will increase, and if this is not done, the desire of the production network to produce that action will decrease .

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• Unsupervised learning

In this learning method, the weights and weights of the neural network are corrected and adjusted only by the system's response. In other words, only the data received from the network environment will be formed into input vectors, and the appropriate output vector will not be applied to the network. In fact, the network does not show any examples of the function on which it is supposed to be trained. At the same time, the reinforcement signal has been removed from the network, and it is enough to reward or punish only in a specialized way.

Neural networks in terms of reversibility

A) Feedforward networks In such networks, only the inputs of each layer affect the performance of that layer. This means that the parameters are set forward, and each layer is responsible for its inputs. In other words, the output of that layer and other layers does not affect that layer. In principle, this mode is called a forward network. b) Feedforward networks In these networks, basically, the output of each layer affects that layer itself and the performance of other layers. The network works in such a way that it tries to rebuild itself based on the output of the target and vice versa for the first state of each layer. Achieving the desired goal not only corrects itself but also adjusts the layers behind it. to these networks that affect both themselves and the neurons before them

Some examples of neural networks

In the following, we define two examples of the most widely used neural networks that are used for various applications, including .classification

•Multilayer Perceptron NetworkMLP

Each neural network consists of three input, middle or hidden layers, and an output layer. One of the most common types of neural networks is

The multilayer perceptron network, often referred to as backpropagation due to its training algorithm, was initially proposed by Rosenblatt. In this network, the input layer serves as a conduit between the external world and the network, with each node simply transmitting the input to the neurons in the next layer. Consequently, the number of nodes in the input layer (R) is equal to the number of independent variables. The number of neurons in the output layer (S) corresponds to the desired number of dependent variables, while the number of nodes in each hidden layer depends on the complexity of the problem at hand .

Backpropagation training is one of the most well-known methods for training neural networks. The steps of this algorithm are outlined as follows :

Step 1: Initialize the weights .

Step 2: Apply each input vector to the network, which propagates through the hidden layer .

Step 3: In the hidden layer, calculate the sum of the inputs multiplied by their corresponding weights, apply an activation function to this sum, and transmit the result to the next layer .

Step 4: Repeat the calculations performed in the hidden layer for the output layer .

Step 5: Calculate the error value for each output and determine the correction values for the weights of the output layer .

Step 6: Determine the error values for the hidden layer and the correction values for the weights of the hidden layer .

Step 7: Update the weights .

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Step 8: Move on to the next input vector and return to Step 2. If all input vectors have been processed, proceed to the next step .
Step 9: Repeat Steps 2 to 8 until a stopping condition is met .
There are various algorithms within the backpropagation method, such as gradient descent batch training, gradient descent with momentum, elastic backpropagation, different gradient combination algorithms, pseudo-Newton algorithms, and the LevenbergMarquardt algorithm. In order to provide a brief introduction to some of the algorithms used in this thesis, the following explanations are given :
Backpropagation: The goal of the backpropagation training algorithm is to mitigate the negative effects on the size of partial derivatives. It determines the weight changes using a separate update value. This algorithm exhibits greater efficiency compared to standard gradient descent algorithms and requires less memory .
Levenberg-Marquardt: Similar to pseudo-Newton methods, this algorithm aims to reduce computations by avoiding the calculation of the Hessian matrix. Consequently, it operates much faster than other algorithms. However, a drawback of the Levenberg-Marquardt method is its requirement for storing large matrices in memory, which can consume significant space .
Scaled Conjugate Gradient (SCG): The SCG algorithm is designed to circumvent time-consuming linear searches. It is a complex algorithm that combines the Gradient Descent and Levenberg-Marquardt methods. It is important to note that there is no one-size-fits-all algorithm that provides an optimal solution for all possible scenarios .

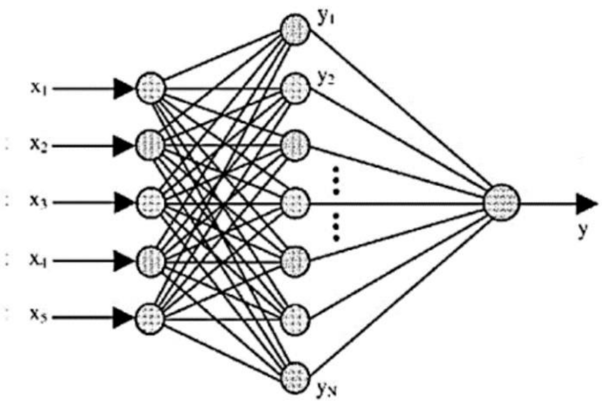

Figure 1. The Radial Basis Function Network (RBF) is a well-known neural network architecture that resembles a multi-layer feedforward neural network .
The primary concept behind designing RBF networks is to mimic statistical pattern classification techniques. These networks utilize bell-shaped surfaces, which are prominent at the center and gradually taper off towards the edges to separate patterns in space. The division of the pattern space is achieved by setting the opening value of the bell-shaped surface, as depicted in the figure below .

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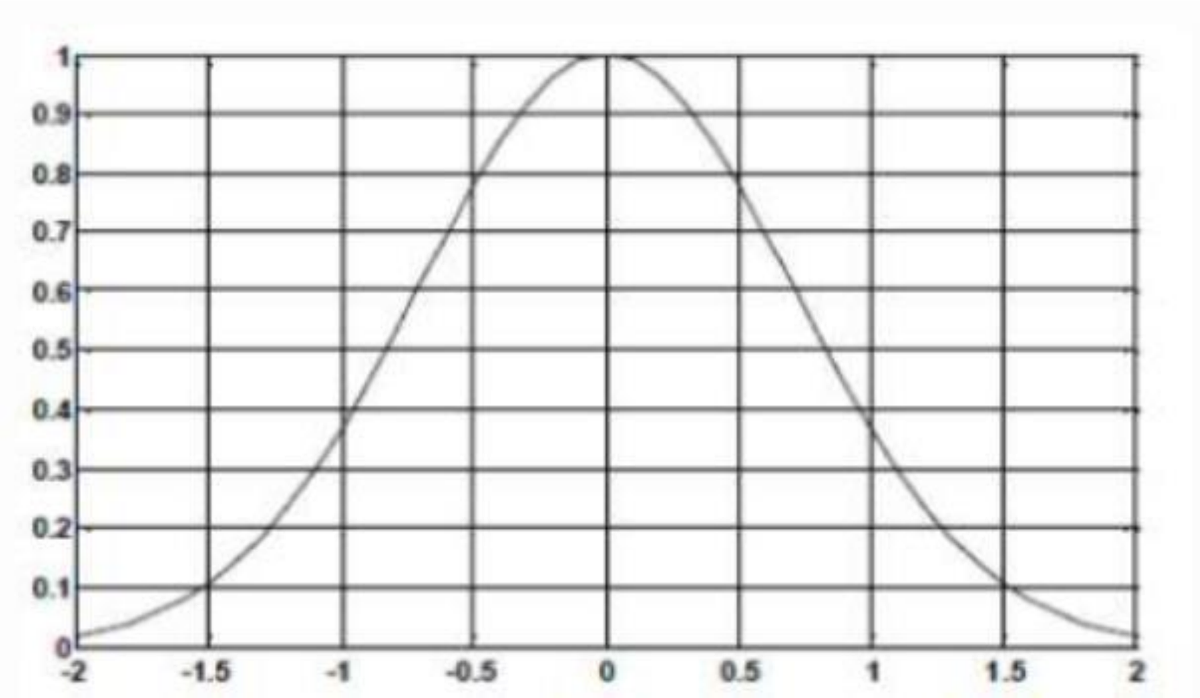

Figure 2

In this network, the input layer is only the place of data entry, and no processing takes place there. The second layer, or hidden layer, establishes a non-linear adaptation between the input space and a space usually with a larger dimension and plays an important role in converting non-linear patterns into linear separable patterns and generally training this part of the network by monitoring method. It is not done. Finally, in the third layer, the network response is obtained by a linear transformation. The activation functions of each hidden unit in a network RBF calculate the Euclidean distance between the input vector and its centre using Gaussian functions. In fact, the output of each hidden unit is the distance between the input data vector and the hidden centre in which it is located. The training of network parameters (weights) between hidden layers and output layers is supervised. In the training of this network, in addition to adjusting the weights, it will be necessary to adjust the centre of the activity functions. Weights are adjusted using the gradient descent method according to the smallest error sum of squares, and the centre of the activity functions in the same way .

Application of Neural Networks

Neural networks have been widely used in many applications such as face recognition, recognition of any pattern such as handwritten letters and numbers, and, in general, pattern recognition problems as well as classification.

Another important application of neural networks is to estimate a function at points where we do not have its value. Of course, neural networks have two other uses for clustering and time series. Today, the advancement of hardware technologies and the invention of faster computers and algorithms have made it possible to use neural networks to solve complex industrial problems. The following is a list of some

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: applications of neural networks in different sciences Air And Space
• Carry and quote

• Banking
• Affairs Defensive
• Electronic _

Methlodgy
In the first step, to do project respectful research and study related to the issue and check works done in this field, we paid for bank informational self-particles for the direct object. Complete we did also Yet From Network Nervous artificial At diagnosis Sickness Hi Different item use taken Is, But At this Project, We intention we have From
Network NervousMLPThat One Network Recurrent nervousness Is. At diagnosis soon when Sickness diabetes Use do It should be noted that the weights output primitive neuron Hi Background Oh you equal to With Half From Domain output cells
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•Method does Work as That It was mentioned earlier. Network Hi Nervous With to have One Ring Feedback Internal capable To learning Identify and Production Patterns when are for this purpose To Entrance this Network From Data Hi ready Norwegian National Institute of HealthUse we did
In this method, we consider a number of parameters to determine the disease of diabetes, as well as based on the experimental data that we mentioned earlier, with the numbers zero and one, whether a person is suffering from diabetes or not is suffering from diabetes based on the same data and parameters. We will put a regular table. Then, using the same data, we have to train the artificial neural network .
The number of neurons and hidden layers is based on some kind of experience. It should be noted that increasing the number of layers, although it increases the accuracy, will increase the complexity of the system .

Coding and analysis
We will examine the codes and implementation of artificial neural network algorithms, explain the different parts of the code in detail, and analyze them. First, we will examine a part of the data that has been adopted based on the reference mentioned in the previous chapter. These data in MATLAB will be as follows .

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04-21-1991	9:09	58	100
04-21-1991	9:09	33	009
04-21-1991	9:09	34	013
04-21-1991	17:08	62	119
04-21-1991	17:08	33	007
04-21-1991	22:51	48	123
04-22-1991	7:35	58	216
04-22-1991	7:35	33	010
04-22-1991	7:35	34	013
04-22-1991	13:40	33	002
04-22-1991	16:56	62	211
04-22-1991	16:56	33	007
04-23-1991	7:25	58	257
04-23-1991	7:25	33	011
04-23-1991	7:25	34	013
04-23-1991	17:25	62	129
04-23-1991	17:25	33	007
04-24-1991	7:52	58	239
04-24-1991	7:52	33	010
04-24-1991	7:52	34	014
04-24-1991	12:00	33	004
04-24-1991	17:10	62	129
04-24-1991	22:09	48	340
04-24-1991	22:09	33	005

.This is part of the data

```
for ii=1:70     M=[];    if ii<10
      n(end-1:end)=['0' num2str(ii)];     else
      n(end-1:end)=num2str(ii);     end
   f=importdata([p n]);
   H=[];     J=[];
   for jj=1:length(f.data)

      L=f.textdata{jj,2};        if length(str2num(L))~=1           J=[J
~isempty(L)];           m=(datenum(L)-
datenum('23:59'))./(datenum('00:00')-
datenum('23:59'));           H=[H;m];        end
end
   a=find(J==1);
   M(:,1)=H;
   M(:,2:3)=f.data(a,:);
```

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```
   P{ii}=M; end
```

Discuss the classification and arrangement of data. Is that data raw before submission direction education network nervous artificial needs have until the to the face special classification become classification and also delete some data i see at code above happening falls down

In the training of neural networks, the data is divided into two categories: all input and target; as mentioned previously ,

41 the neural network is a set of paths with different weights, which finally _ forms the output based on the input. give

This division of data into input and output is done and applied in the following code. In this research, the inputs are a set of medical criteria based on which diabetes is diagnosed. The output is a binary parameter in the form of a row and one, where zero equals not having the disease

```
for ii=1:length(P)    H=P{ii};
   input=[input; [ii.*ones(length(H),1) H(:,1:2)]];    output=[output;H(:,3)]; end
```

. .and one means having diabetes

In the following, we will define the type of neural network and its structure and details, including the number of layers, the number of

```
ratio=0.8;
N=ratio.*length(output);          L=randperm(length(output));          inputtr=input(L(1:fix(N)),:);
inputte=input(L(1+fix(N)):end,:);                                      outputtr=output(L(1:fix(N)),:);
outputte=output(L(1+fix(N)):end,:);
net=newff(input',output',[10 10],{'purelin'
'purelin'});
net=train(net,input',output');
```

Neurons, and such things. In MATLAB, this part will be coded asfollows

As it is known, the neural network used in this research is a forwardbackward propagation type. This department also does training .

```
y=sim(net,inputte');
mse(y,outputte')
```

Finally, the simulation and application of new inputs to the designed neural network, as well as the calculation of the error rate, are performed by the following code

Results and analysis

Review the results, output, and analysis. We will pay what we have designed as a neural network. The results and output of the artificial neural network based on the data mentioned earlier are . as follows

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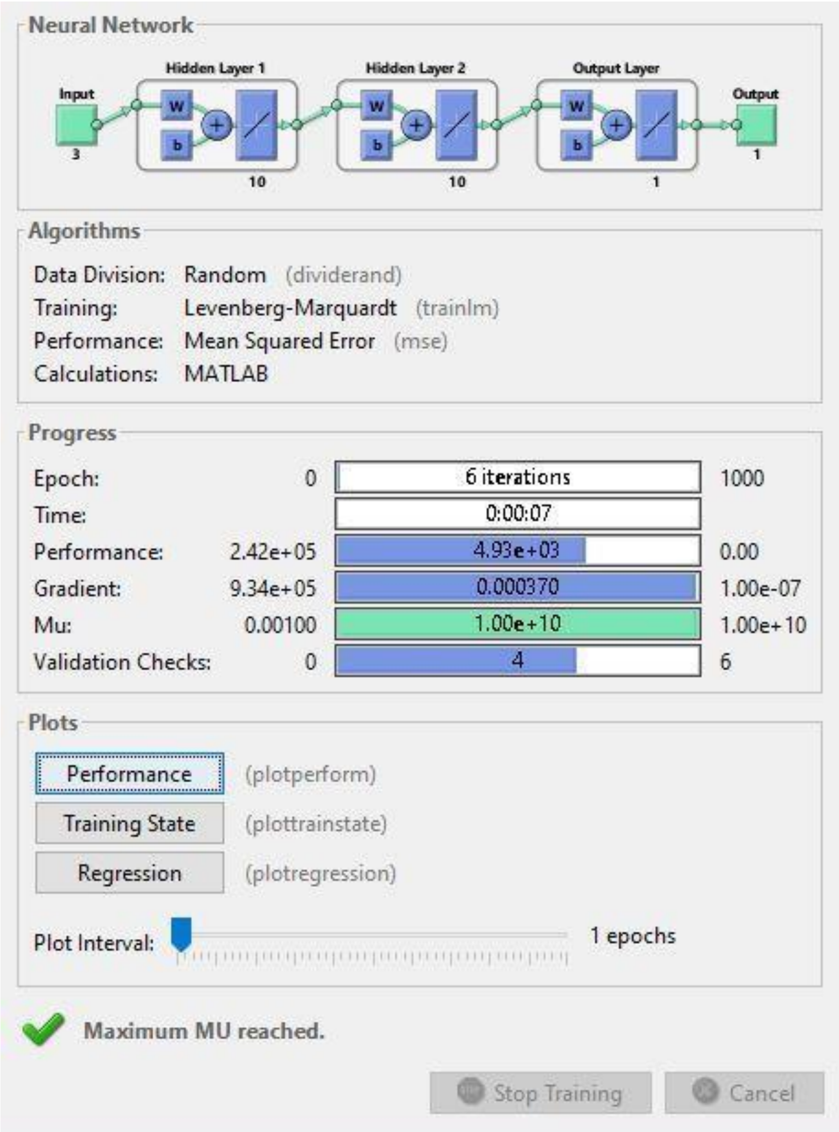

Best Validation Performance is 5161.7075 at epoch 2

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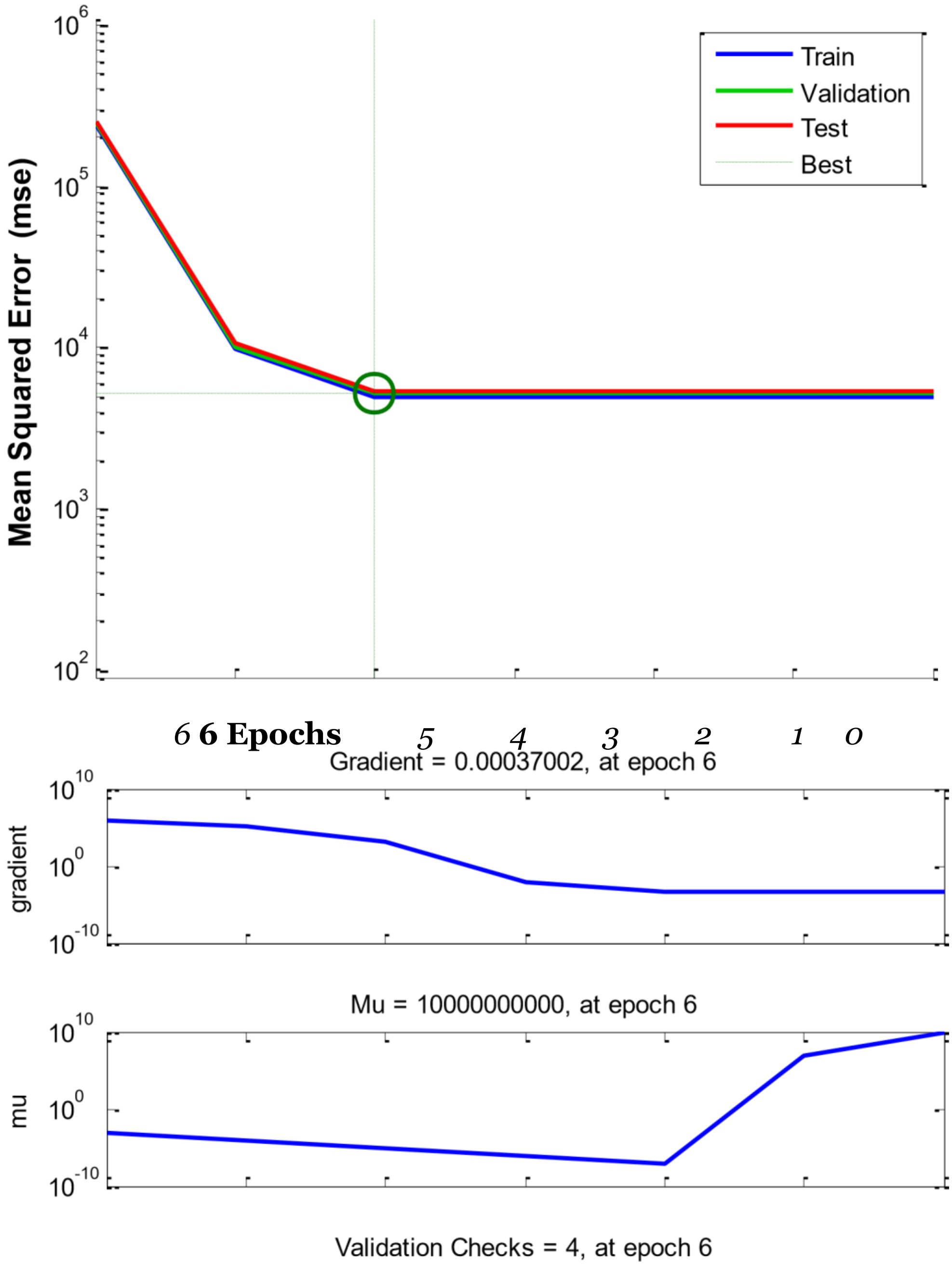

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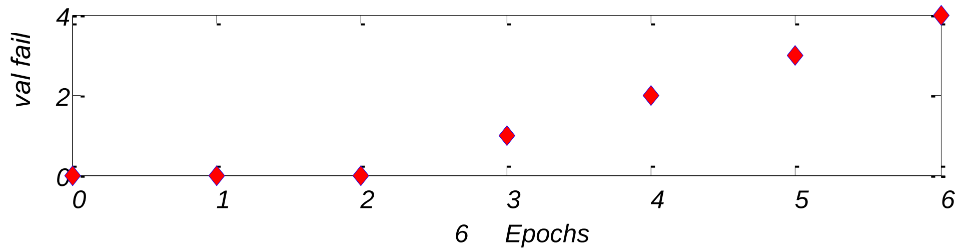

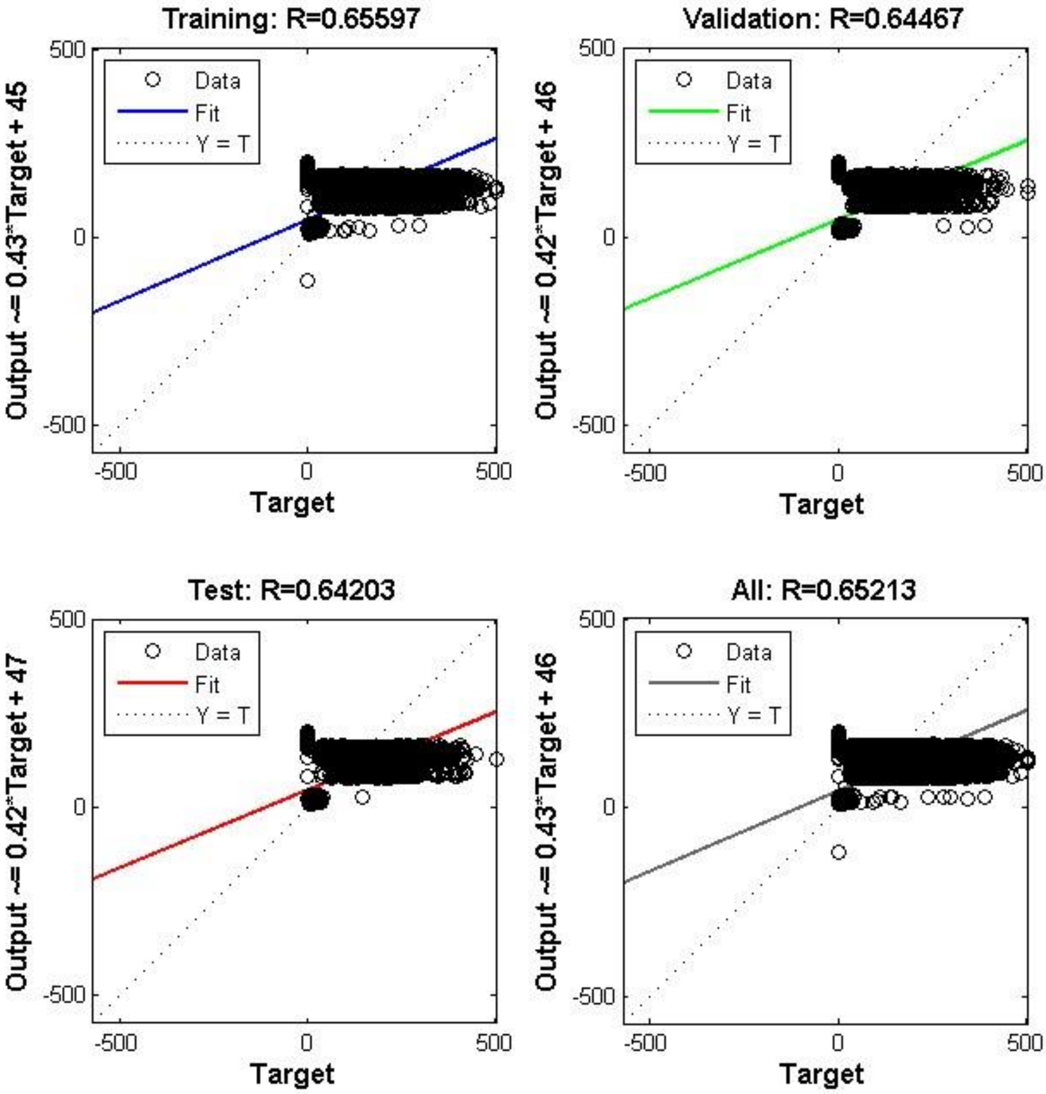

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As it is clear from the results, the neural network has been able to fit the data well. The graphs show that the training was done in the least number of repetitions, and this shows the efficiency of the designed neural network. Also, the data fitting part shows that the output has a very close relationship with network training. Also, the distanced error and standard deviation based on the outputs of the neural network are as follows .

ans =

6.617012045908403e-03

This result also shows the function and efficiency of the designed network .

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