Decision Support System for Congenital Heart Disease Diagnosis based on Signs and Symptoms using Neural Networks

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ABSTRACT
Congenital Heart Disease is one of the major causes of deaths in children. However, a proper diagnosis at an early stage can result in significant life saving. Unfortunately, all the physicians are not equally skilled, which can cause for time delay, inaccuracy of the diagnosis. A system for automated medical diagnosis would enhance the accuracy of the diagnosis and reduce the cost effects. In the present paper, a Decision Support System has been proposed for diagnosis of Congenital Heart Disease. The proposed system is designed and developed by using MATLAB's GUI feature with the implementation of Backpropagation Neural Network. The Backpropagation Neural Network used in this study is a multi layered Feed Forward Neural Network, which is trained by a supervised Delta Learning Rule. The dataset used in this study are the signs, symptoms and the results of physical evaluation of a patient. The proposed system achieved an accuracy of 90%.

Keywords
Congenital Heart Disease, Disease Diagnosis, Decision Support System, Backpropagation Neural Network.

1. INTRODUCTION
The studies made on *prevalence of Congenital Heart Disease in India* [1] shows that the number of children suffering with Congenital Heart Disease is on a rise from year to year. Congenital Heart Disease occupies one third of all the types of the diseases that a child suffers from their infancy. If these defects are not recognized and treated properly at an early stage of the children, they have to face many problems in their future or even they have to lose their lives at their childhood itself. But recognizing Congenital Heart Defects at right time is a difficult task for Physicians due to lack of subject specialists or inexperience with the previous cases or even as the children they can't express their problem in a proper way.

In order to improve the diagnosis accuracy and to reduce the diagnosis time, it has become a demanding issue to develop an efficient and reliable medical Decision Support System to support yet and still increasingly complicated diagnosis decision process. Hence soft computing methods such as neural networks have shown great potential to be applied in the development of medical Decision Support System for Heart Diseases [2].

The various techniques of Artificial Neural Network applied for the diagnosis of heart diseases [3] successfully are: A simple Multi Layer Percepton is used for prediction of Heart Attack [4] and to design a Decision Support System for Heart Disease Diagnosis [5], A BackPropagation Neural Network model is applied to diagnose Heart Value Diseases [6] and to design a decision Support System for Heart Disease Diagnosis [7], A Multichannel Adaptive Resonance Theory is used for Heart Disease Diagnosis successfully [8]. As these models gave more accurate results in the diagnosis of heart diseases, in the present study also BackPropagation Neural Network model has been implemented for the classification of Congenital Heart Disease Diagnosis based on Signs, Symptoms and Physical Examination of a patient.

The present paper is organized as follows. Section 2 describes about an introduction to Congenital Heart Defects, Causes and its effects (signs and symptoms). The proposed methodology of Backpropagation Neural Network Model is given in section 3. The design and implementation of Decision Support System for Congenital Heart Defect diagnosis is presented in detail in section 4 and finally conclusion is given in section 5.

2. CONGENITAL HEART DEFECTS
Congenital Heart Defect (CHD) is a problem that occurred as the baby's heart was developing during pregnancy, before the baby is born. Congenital Heart Defects are the most common birth defects. Nine out of every 1,000 babies born in India have a Congenital Heart Defect. Congenital Heart Defects happen because of incomplete or abnormal development of the fetus' heart during the very early weeks of pregnancy. Some are known to be associated with genetic disorders, such as Down syndrome, but the cause of most Congenital Heart Defects is unknown [9].

The various types of Congenital Heart Defects classified into these major categories. ***Holes in the heart*-**these are holes in the walls between heart chambers or between major blood vessels leaving the heart [10]. These holes allow oxygen-rich and oxygen-poor blood to mix. Not having enough oxygen in the blood can cause the *child's skin or fingernails to appear blue in color*. The baby may also develop signs and symptoms of *congestive heart failure*, *shortness of breath*, *irritability* and *leg swelling*, because both oxygen-rich and oxygen-poor blood are flooding (over circulating) the lungs. Examples of hole defects include Ventricular Septal Defect (VSD), Atrial Septal Defect (ASD) and Patent Ductus Arteriosus (PDA); ***Obstructed blood flow***-When blood vessels or heart valves are narrow because of a Heart Defect, the heart must work harder to pump blood through them. The most common of this type defect is Pulmonary Stenosis, Aortic Stenosis [11]. The narrowed valve forces the

heart muscle to work harder, eventually leading to thickening and enlarging of the muscle. If the Stenosis is severe, especially in babies, some *cyanosis (blueness)* may occur. ***Abnormal blood vessels***-Several Congenital Heart Defects involve incorrectly formed or positioned blood vessels going to and from the heart.

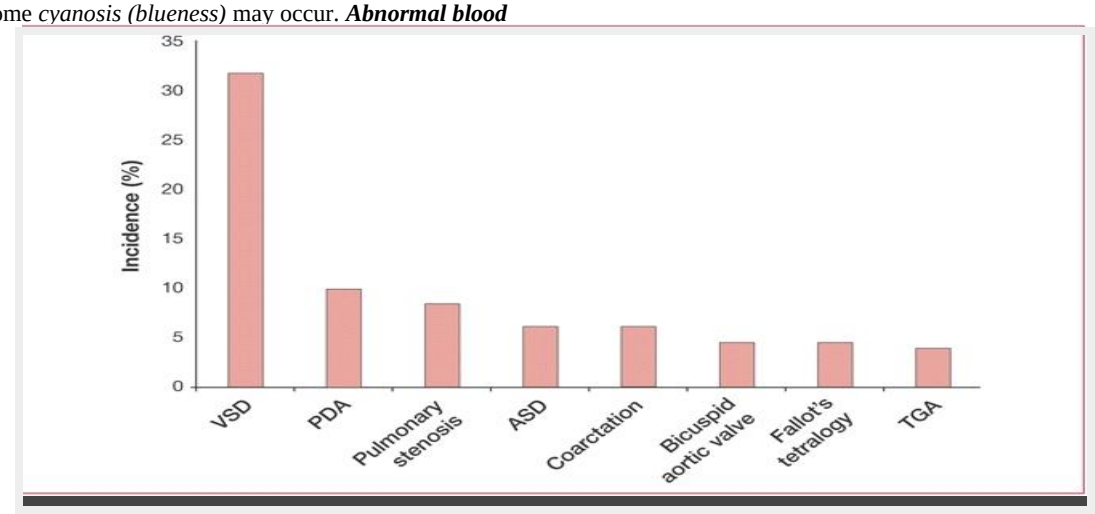

Figure 1: Percentage of Occurrences of various Congenital Heart Defects

For example, Transposition of the Great Arteries (TGA), most babies with Transposition of the Great Arteries are extremely *blue (cyanotic)* soon after birth because these connections are inadequate.

Heart valve abnormalities-If the heart valves can't open and close correctly, blood can't flow smoothly. Examples include Ebstein's Anomaly [12], in which the tricuspid valve is malformed and often leaks, and pulmonary atresia, in which a piece of heart tissue blocks normal blood flow to the lungs. Both defects prevent oxygen-poor blood from circulating to the lungs. *A **combination of defects***-Some infants are born with several Heart Defects. For example, Tetralogy of Fallot [13] is a combination of four defects: a hole in the ventricular septum, a narrowed passage between the right ventricle and pulmonary artery, a shift in the connection of the aorta to the heart, and thickened muscle in the right ventricle. This results in *cyanosis (blueness)*, which may appear soon after birth, in infancy or later in childhood. These "blue babies" may have sudden episodes of severe cyanosis with *rapid breathing*. They may even become *unconscious*. During exercise, older children may become *short of breath and faint*. These symptoms occur because not enough blood flows to the lungs to supply the child's body with oxygen. The percentage of, occurrences of various types of Congenital Heart Defects are shown in figure 1.

If these defects are not recognized and treated properly at an early stage of the children, then they have to face many problems in their future or even they have to lose their lives. But recognizing Congenital Heart Defects at right time is a difficult task for Physicians, because some Congenital Heart Defects may have Symptoms and some may not have and also as the children they can't express their problem in a proper way.

3. BACKPROPAGATION NEURAL NETWORK

Backpropagation Neural Network is a multilayer Feed Forward Neural Network Model [14] which contains one input layer, one output layer and one or more hidden layers. As the name implies the input layer receives signals from the external nodes and transmits these signals to other layers without performing any computations at that layer. The output layer receives the signals from an input layer through a weighted connection links, performs computations at that layer and produces output of the network. The hidden layer of a network receives signals from an input layer through a weighted connection links, performs the computation and transmits these results as signals to the output layer through a weighted connection links w_{11}, w_{12}, . . . w_{pm}. The hidden layer of a network is neither an input layer nor an output layer instead it acts as input or output layer based on situation. The architecture of a Backpropagation Neural Network Model [15] is shown in Figure 2.

Neural Network is trained by using Generalized Delta Rule also called as Backpropagation Rule [16]. Training a Backpropagation Network involves three stages. First stage is the Feed Forward phase of input training pattern, in which each of the hidden nodes Z_j receives the input signals x_1, x_2, ... , x_n from input nodes X_i through connection weights v_{11}, v_{12} . . . v_{np}, computes the net input as the sum of the products of the input signal and weights i.e $Z_{inj}=v_{0j}+\sum x_i v_{ij}$, applies an activation function to produce the response and finally sends these signals to the output nodes Y_k. Similar to hidden nodes, each of the output nodes Y_k receives the signals z_1, z_2, ... z_p from the hidden nodes Z_j through the connection weights w_{11}, w_{12}, . . . ,w_{pn}, calculates the net input as $y_{ink}=w_{0k}+\sum z_j w_{jk}$, applies an activation function to produce the output of the network. An activation function that is used at both hidden and the output layer is a sigmoid function i.e $f(x) = 1/(1+\exp(-x))$.

Once the response of the net is calculated then each output node compares its response with the target values t_k to determine the associated error. Based on these error the factor δ_k is determined as $\delta_k = (t_k-y_k)*f^1(y_{ink})$. $\delta_k$is used to distribute the errors at Y_k back to all the hidden nodes that are connected to Y_k. Similarly factor δ_j is computed as $\delta_j = \delta_{inj} *f^1(z_{inj})$ for each hidden node Z_j to propagate errors back to input layer. Once all the δ factors are

determined and propagated to appropriate layers, then the weights are adjusted simultaneously. The weight adjustment from hidden node to output node is based on the δ_k as $\Delta w_{jk}=\alpha\ \delta_k\ z_j$ and the weights between the hidden node to input node is based on the factor δ_j as $\Delta v_{ij}=\alpha\ \delta_j\ x_i$. Therefore the new weights

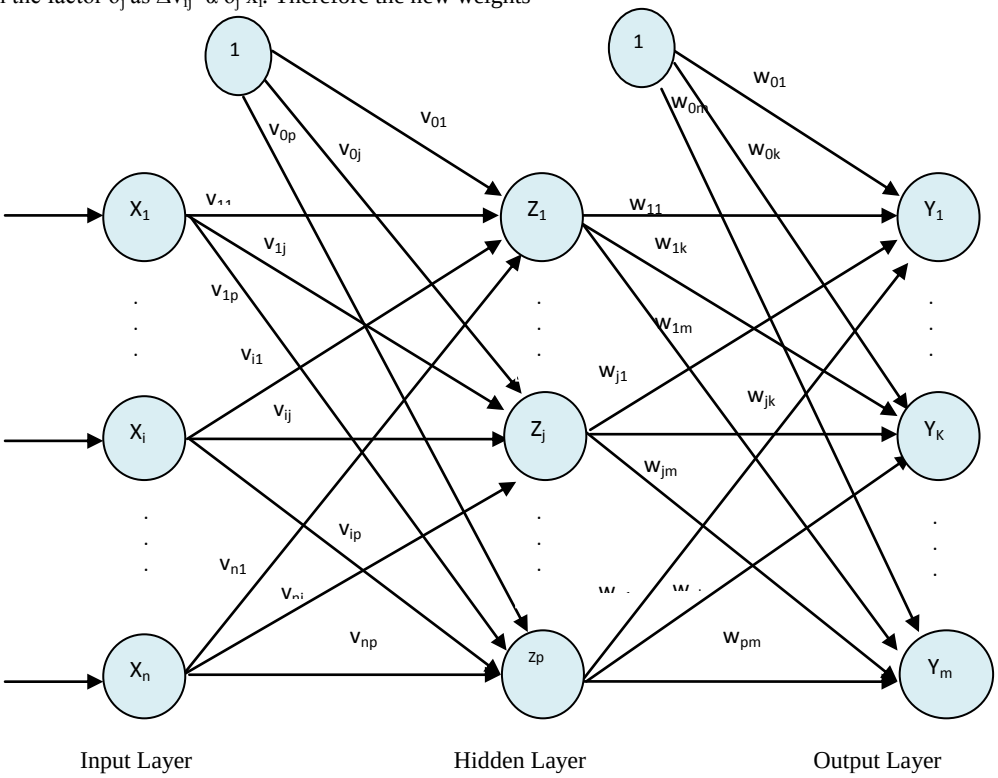

Figure 2: Architecture of a Backpropagation Neural Network Model

between the input nodes and hidden nodes are $v_{ij}(new)=v_{ij}(old)+\Delta v_{ij}$, $v_{0j}(new)=v_{0j}(old)+\Delta v_{0j}$ and the new weights between the hidden nodes and output nodes are $w_{jk}(new)=w_{jk(}old)+\Delta w_{jk}$, $w_{0k}(new)=w_{0k}(old)+\Delta w_{0k}$. This process is continued until the stopping condition. The stopping condition may be the minimization of mean squared error (MSE) value or the number of epochs it has reached. The least mean squared error (MSE) can be computed as $MSE=0.5\sum (t_k-y_k)^2$.

4. DECISION SUPPORT SYSTEM FOR CONGENITAL HEART DEFECT DIAGNOSIS

Congenital Heart Defects are basically diagnosed in two stages. These stages are Physical Evaluation and Clinical Evaluation of a patient. During Physical Evaluation stage, a physician gets the signs, symptoms of a patient and also records the measurements like Systolic Blood Pleasure, Diastolic Blood Pleasure and Heart Beat Rate etc. A patient has been suspected based on these signs, symptoms and measurements only. If a patient gets suspected in the first stage it self then only he orders for the second stage tests (Clinical evaluation).

But suspecting a disease at first stage is not an easy task, because some children may have signs and symptoms and some may not have, in which the diagnosis depends on only the Physical Evaluation of a patient and the decision taken by the physician.

In some situations, a physician may fail to suspect a disease during the first stage itself because of not being a specialist or in experience with the previous cases. In which there is a chance for taking a wrong decision. If he takes a wrong decision by not suspecting a disease at the first stage then he never orders for the second test, where a disease can detected. In this case even though if a child has a defect it won't be detected which causes, the patient to enter into the severe condition. Also if he takes a wrong decision by suspecting a child at the first stage itself and orders for the second test then even though the child doesn't has a defect, he should be clinically tested which causes for more time to know the results and is a cost effective.

These drawbacks can be overcome by using Neural Network Techniques. In the present study a most frequently used BackPropagation Neural Network Model is used to perform the Congenital Heart Disease Diagnosis classification based on the signs, symptoms and physical evaluation of a patient which are given in the below table. Since the Neural Network solutions will not depends on algorithmic solution instead it depends on examples of the previous cases it gives more accurate results than the human diagnosis.

4.1 Parameters Used

The parameters that are used to perform Congenital Heart Disease Diagnosis classification is the signs, symptoms and measurements that were taken from the patients. In the present study a total number of 200 samples were used, each sample is having a set of 36 input parameters and one output parameter.

The parameter names and the allowed values for that are described in Table 1.

Table 1: Attribute Names, Description and their Allowed Values

#No	Attribute	Description	Values
1.	Age	Patient's Age	Continuous
2.	Gender	Patient's Gender	Continuous
3.	Fatigue	Feeling very tiredness due to overflow of blood	Binary
4.	Shortness of Breath	Unable to take a normal breath	Binary
5.	Headache	A pain in the head or neck due to defect in the heart	Binary
6.	Sweating	Due to tiredness (if a defect present in heart)	Binary
7.	Cold	Symptom of Chest Infection.	Binary
8.	Problem of Feeding	Children can face problem while feeding due to shortness of breath	Binary
9.	Less Weight	If a defect present in the heart, children loss normal weight.	Binary
10.	Easily Tiring	Getting tiredness during exercise due to defect in the heart.	Binary
11.	Cough	Comes due to chest infection (which brings up phlegm).	Binary
12.	Chest Pain	Getting pain in the chest due to abnormal flow of blood.	Binary
13.	Clubbing	The proliferation of soft tissue around the ends of fingers.	Binary
14.	Hypertension	Due to high blood pressure (which occurs due to the mixing of blood).	Binary
15.	Palpitations	Periods of rapid and irregular heartbeats (Due to overflow of blood).	Binary
16.	Fever	Infection caused by bacteria	Binary
17.	Dyspnea	Shortness of breath	Binary
18.	Dizziness	Due to low blood pressure, cardiac arrhythmias.	Binary
19.	Vomits	Common symptoms for Acute Myocardial Infection (AMI).	Binary
20.	Diarrhea	Symptom for a Congenital Heart Defect.	Binary
21.	Chest Infection	Is a bacterial or viral infection of the airways leading down into the lungs	Binary
22.	Syncope	Is a sudden or temporary loss of consciousness or Fainting	Binary
23.	Trauma	Impaired blood flow to the lungs.	Binary
24.	Build up of blood and fluid in lungs, feet ankles and legs	Which occur as symptom of a defect in the heart.	Binary
25.	Systolic B.P	Maximum pressure in the arteries during the cardiac cycles, which occurs when the heart contacts or beats to pump blood.	Continuous
26.	Diastolic B.P	Refers to the pressure that is exerted on the walls of the various around the body in between heart beat when the heart is released.	Continuous
27.	Heart Beat	A cardiac cycle of the heart.	Continuous
28.	Cyanosis	Is a severe condition indicates lack of oxygen in the blood supply causes a bluish tint to the skin, lips and finger nails.	Binary
29.	Edema	Swelling of organs or body tissue.	Binary
30.	Thrill	Chest wall vibrations of sufficient intensity to be recognized by tactile sensation.	0 or 1 Binary
31.	Cardiac Failure	Is a condition in which the heart function as a pump to deliver oxygen rich blood to the body is inadequate to meet the body's need.	Binary
32.	Regurgitation	Is characterized by diastolic reflex of blood from the aorta into the ventricle.	Binary
33.	Systolic Murmur	Heard when the heart is squeezing and pumping blood out of the heart.	Binary
34.	Diastolic Murmur	Heard when the heart is relaxing and filling with blood.	Binary
35.	Both Murmurs	Heard during the entire heartbeat signs of a heart defect	Binary
36.	Anemia	Anemia is a common in acquired heart failures and affects prognosis.	Binary

4.2 Experiments and Results

4.2.1 Experiment

A Decision Support System for Congenital Heart Disease Diagnosis is designed by using MATLAB's GUI feature and is developed by using MATLAB 7.3 [17] and implementing the Backpropagation Neural Network Model. Initially a BackPropagation Neural Network is built with 36 input nodes, 10 hidden nodes and one output node using MATLAB 7.3. The network is trained using a supervised training and a Delta Learning Rule. 200 samples are used to train and test the

network. Among these samples, 80% of the data are used for training and 20% of the data are used for testing purposes. Once the Network is trained using these samples, then for a new pattern it does the classification automatically. The least MSE value for the present experiment is 0.016.

The developed Decision Support System can be used by a physician to automatically diagnose Congenital Heart Defects by entering the basic information, signs and symptoms of a patient. The proposed system reduces the diagnosis time of a physician and also increases the accuracy of the diagnosis. The proposed system is not only used for diagnosis, instead it can also be used to store and view the results of the diagnosis for future reference.

4.2.2 Results

The results of present experiment are shown in the following figures. Figure 3 shows the diagnosis result for a person who suffers with Congenital Heart Defect and Figure 4 shows the diagnosis result for a normal person.

From the present experiment, it shows that if a patient has any of the symptoms like Dyspnea, Shortness of Breath, Chest Pain and Cyanosis then a patient gets suspected. Also it shows that the percentage of suspecting Congenital Heart Disease will be more if a patient has any murmurs like systolic or diastolic or both murmurs and the sounds of S1, S2. Therefore, the present experiment gives more accurate results once the sign and symptoms of a patient are clearly known. The accuracy achieved through the proposed system is 90%. Since the Solutions of Neural Networks will not depend on the algorithmic solutions it gave the accurate results when comparing to manual diagnosis.

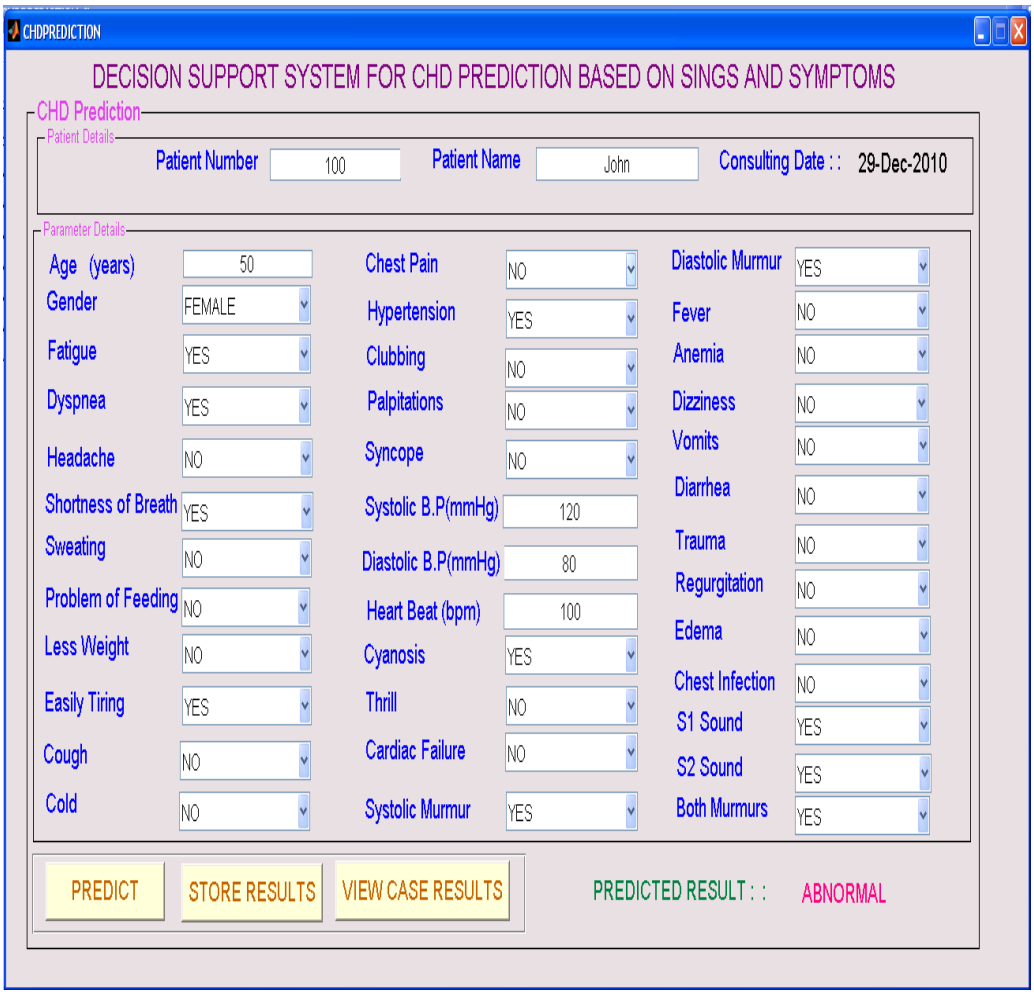

Figure 3: Results of Congenital Heart Disease diagnosis of abnormal person

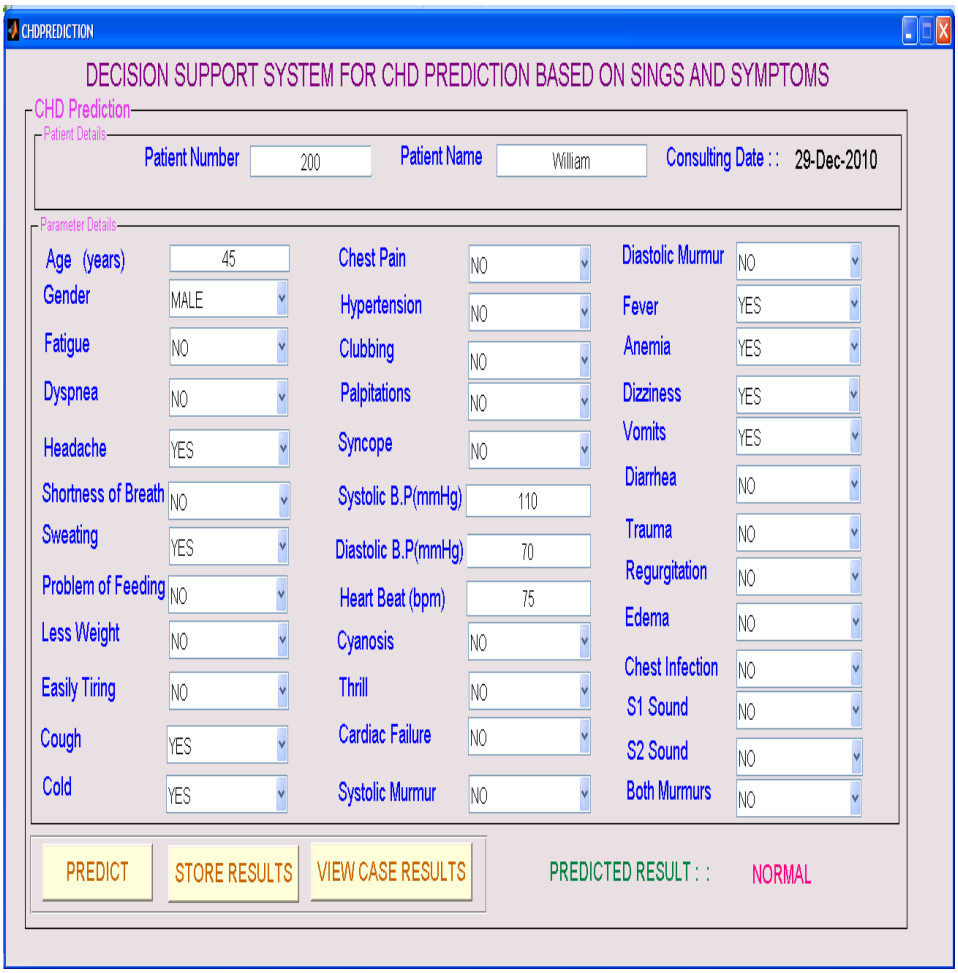

Figure 4: Results of Congenital Heart Disease diagnosis of normal person

5. CONCLUSION

As the population increases day by day the number of children suffering, with Congenital Heart Diseases are also in rise. This increases the unavailability of physicians and also the inaccuracy of the diagnosis. This paper presents a Decision Support System for Congenital Heart Disease diagnosis which can speed up diagnosis process, improves the accuracy of the diagnosis and reduces the cost without loss of diagnostic performance. The proposed system also decreases the number of diagnostic tests and predicts the disease at an early stage of the disease. Therefore the present system gives a better performance when comparing with the manual diagnosis.

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