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An Expert System for Home Health Monitoring: The ANFIS Approach

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Abstract- Healthcare is approaching a critical situation. The ageing of population is increasing the prevalence of chronic diseases. Cardiovascular and respiratory diseases not only kill hundreds of thousands of people each year around the globe but also cost billions of dollars. Patients have to make frequent visits to their doctor to get their vital signs measured. People in remote places are deprived of proper healthcare. Hence, there is a need to develop a system which will help in reducing the frequent visits to the clinic and also help in early diagnosis of dangerous diseases. A system must be targeted both for monitoring elderly and for monitoring rehabilitation after hospitalization period and at the same time economically efficient. This paper presents our initial attempts to develop such a system with the help of Adaptive Neuro-Fuzzy Inference System (ANFIS) by adaptive learning mechanism. The MATLAB simulation results indicate that the performance of the ANFIS approach is valuable and easy to implement. The developed healthcare system can be useful for the elderly and terminally ill patients confined within their homes and at the same time helpful to the pregnant women for their regular checkups without personally visiting to the clinic.
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Index Terms- Adaptive Neuro-Fuzzy Inference System, adaptive learning mechanism, healthcare, health monitoring, rehabilitation

I. Introduction

Health concerns all of us. Information and communication technologies (ICTs) are increasingly providing us with the tools and knowledge that we need to improve health care, enabling solutions that benefit patients as well as healthcare professionals and institutions in both the private and public sectors worldwide. Home health monitoring can serve as a vehicle for the transformation of health conditions in the developing world, particularly for those living in rural and remote areas. Ageing of population, growing mobility in society and growing shortage of staff resources in the health care sector require new models for information handling and communication in order to guarantee quality-oriented health care of the elderly. However, to assure high quality health services for the elderly at a reasonable cost, standardized co-ordination of information handling and communication between different care providers is a prerequisite. As the population grows older, people becomesincreasingly dependent as their sensory, motor and cognitive physiological health capacities deteriorate; these age related changes, are amplified if they are accompanied by pathological conditions that are common in the elderly population. Most European countries are now facing an urgent requirement to provide appropriate retired home environments solutions for these citizens and allow them to play a role in our society. Patients have to make frequent visits to their doctor to get their vital signs measured.Regular monitoring of vital signs is essential as they are primary indicators of anIndividual's physical well-being.

The vital signs include:
1. Pulse rate
2. Blood pressure
3. Body temperature
4.Oxygen saturation level

Traditionally, it was a custom to get these vital signs measured during a visit to the doctor. With advances in medicine and technology, this concept has adapted. There are many devices available in the market today that allow patients to monitor their own health on a regular basis from the comfort of their home. These devices are having a huge impact on health care costs as they are reducing the time and resources of medical physicians and facilities required by patients. This is advantageous for both patients and physicians. Patients can monitor their health regularly and adjust their diet and physical exercise as needed to keep their vitals in balance. Health care professionals can access this information from their computers via wireless network and can check their patients' vitals at their own time. If theynotice abnormalities, they can always schedule an appointment with their patients. This paper presents our initial attempts to develop a low cost, reliable, non-intrusive,and non-invasive vital signs monitorthat processes and analyses the data acquired frommeasuring instruments to determine if an individual is within a "normal" range. Most of the population of India is located in the rural areas which are deprived of the proper health care facilities. Hence, whenever they want the health care services they have to make the regular and most frequent visits to the city hospitals. This proves to be cost ineffective with a lot of inconvenience to the patient as well as his family members. The proposed system will prove to be cost effective and convenient in such case. One of the diversified applications of this work is to monitor the regular health status of a pregnant woman at home.

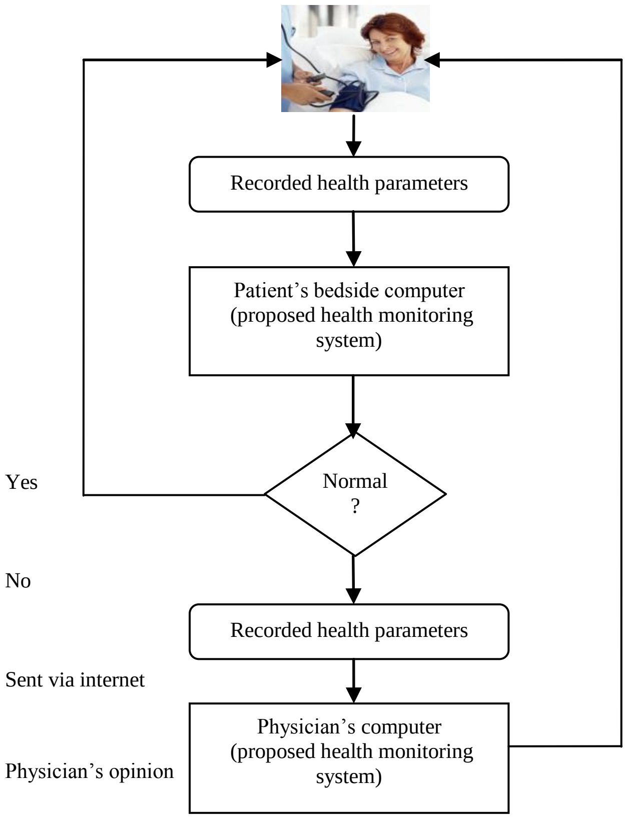

Figure1. Health Monitoring Workflow

Neural Fuzzy Systems can create fuzzy rules and membership functions for complex systems for which the fuzzy approach may fail, limiting themselves to lesser number of rules. This limits the performance and accuracy of the system. Whereas, the neural networks have the ability to adapt itself to the changes in input until the output matches the desired value increasing the reliability of the system. Hence a combination of fuzzy logic and adaptive nature of neural network is made use for detecting the health status of an individual. The neuro-fuzzy systems can handle any type of information (numerical, linguistic, logical, etc.), manage imprecise data and are self-learning. Hence it minimizes the human decision making process [1].

The patient is checked for vital health parameters with the help of portable digital instruments such as pulseoxymeter, thermometer and blood pressure monitor. The measured parameters are then given as input to the proposed system. If the outcome represents that the patient is abnormal then the appropriate medications are provided by the physician. This is illustrated in figure.1 above. Family-based healthcare services allow patients full mobility at their homes, where health-care providers can monitor their health data remotely. Such family-based connected healthcare systems besides reducing the waiting time for face-to-face contact with physicians are capable of generating alerts being sent to the patients or to the informal care-taker by the physician [2].

The paper is structured as follows. In section 2, a survey on related work is discussed. Section 3, explains the proposed work where the processes involved in neuro-fuzzy based classification are discussed. Results are discussed in section 4 followed by conclusions and future work to be carried out in section 5.

II. RELATED WORK

Ibrahim Khalil et al., [3] developed an advanced prediction model so as to estimate the heart rates of selected patients in a mobile care system. Koji Mukai et al., [4] developed a remote system formonitoring respiration rate, heart rate and movement behaviour of at-home elderly people who are living alone. Hiroshi Nakajima et al., [5] described a human health monitoring system by an air pressure sensor and an ultrasonic sensor system. K. Kuwanaet al., [6] developed an implantable telemetry capsule for monitoring the heartbeat patient. Mari Zakrzewski et al., [7] developed the system which was targeted both for monitoring elderly and for monitoring rehabilitation after hospitalization period.

Shoko Nukaya et al., [8] described a novel bed sensing method for non-invasive, constraint-free and subliminal detection of biosignals. Kyung-Ah Kim et al., [9] implemented a home self healthcare monitoring system which can monitor respiration, blood glucose, urinary flow, and temperature. Dr. V. Vaidehi et al., [10] proposed health care monitoring system enables significant responsiveness and process optimization by integrating complex event processing. A method using the combination of ZigBee and GPRS is presented by Hongzhou Yu et al., [11] which is a remote health monitoring system to collect and transfer biosignal data from the patient to healthcare center. This system transfers the data effectively but is not capable of decision making.NamrataNawka et al., [2] presented “SESGARH”, a scalable and extensible smart-phone based healthcare system, to provide realtime continuous monitoring of health conditions of individuals seeking professional healthcare. A real-time system for detecting the fall of elderly people in smart home is presented by V. DhivyaPoorani et al., [1]. All the above approaches for health monitoring are beneficial but at the same time they have some limitations ranging from complexity to cost. Hence, there is a need to develop the proposed ANFIS based health monitoring system.

III. ADAPTIVE NEURO-FUZZY INEFERNCE SYSTEM

The Adaptive Neuro-Fuzzy Inference System technique was originally presented by Jang in 1993 [12]. ANFIS is a simple data learning technique that uses Fuzzy Logic to transform given inputs into a desired output with the help of highly interconnected Neural Network processing elements and information connections, which are weighted to map the numerical inputs into an output. ANFIS combines the benefits of the two machine learning techniques (Fuzzy Logic and Neural Network) into a single technique [12]. An ANFIS works by applying Neural Network learning methods to tune the parameters of a Fuzzy Inference System (FIS).

The ANFIS system training methodology is summarized in Fig. 2. The process begins by obtaining a training data set (input/output data pairs) and testing data sets. Two vectors are used to train the ANFIS system: input and output vector. The training data is a set of input and output vectors. It is used to find the premise parameters for the membership functions. A threshold value for the error between the actual and desired output is determined.The consequent parameters are found using the least squares method. If this error is larger than the threshold value, then the premise parameters are updated using the gradient decent method. The process is terminated if the error is less than the threshold value [12]. ANFIS training learning rules use hybrid learning, combining the gradient descent and the least squares method.aim of using ANFIS for health monitoring is to achieve the best performance possible. ANFIS training begins by creating a set of suitable training data in order to be able to train the Neuro-Fuzzy system.

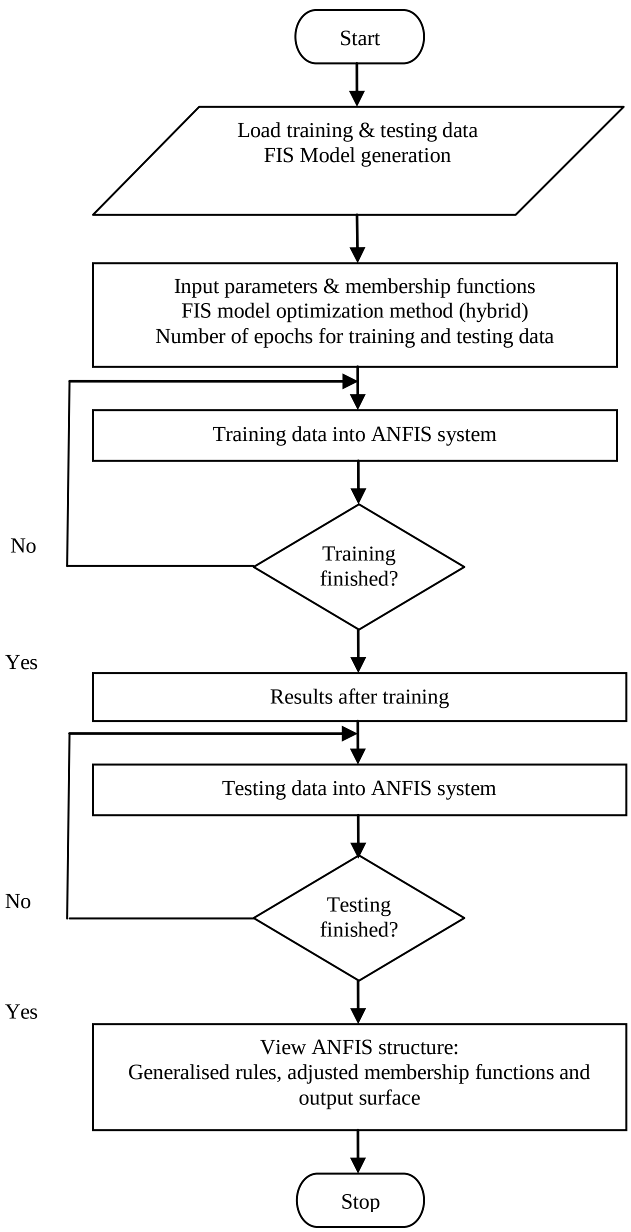

Figure2. ANFIS Training system

The data set used as the input to the ANFIS function must be in a matrix form, where the last column in the matrix is the output, and the matrix contains as many columns as needed to represent the inputs to the system. The rows represent all the existing data situations. Once the initial membership functions are created, system begins training. When the training process is finished the final membership functions and training error from the training data set are produced. After the system training is complete, ANFIS provides a method to study and evaluate the system performance by using the evalfis function. Once the ANFIS is trained, we can test the system against different sets of data values to check the functionality of the proposed system [13].

To implement and test the proposed architecture, a development tool is required. MATLAB Fuzzy Logic Toolbox (FLT) from MathWorks was selected as the development tool. This tool provides an environment to build and evaluate fuzzy systems using a graphical user interface. It consists of a FIS editor, the rule editor, a membership function editor, the fuzzy inference viewer, and the output surface viewer. The FIS editor displays general information about a fuzzy inference system. The membership function editor is the tool that displays and edits the membership functions associated with all input and output variables. The rule editor allows the user to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item. The rule viewer allows users to interpret the entire fuzzy inference process at once. The ANFIS editor GUI menu bar can be used to load a FIS training initialization, save the trained FIS, and open a new Sugeno system to interpret the trained FIS model.

IV. RESULTS AND DISCUSSION

The data were divided into two separate sets: the training data set and the testing data set. The training data set was used to train the ANFIS, whereas the testing data set was used to verify the accuracy and the effectiveness of the trained ANFIS model. The optimal ANFIS model setting will be selected based on the minimum training and testing error values for number of epochs. The Gaussian membership function is taken into consideration for the better results. The ANFIS system was structured by selecting five inputs namely: SystolicBP, DiastolicBP, PulseRate, OxygenSaturation, and Temperature having 3,3,3,2,2 membership functions respectively and one output as Health Status. The generated fuzzy inference system structure contains 108 fuzzy rules.

The ANFIS model structure is as shown in the figure 3below. The five inputs each having the membership functions are represented. With the help of these membership functions the rules are constructed and accordingly an output is generated. There are 108 rules (3*3*3*2*2)for five inputs and one output.

The additional information about the developed ANFIS system is as follows:

1) Number of nodes: 250
2) Number of linear parameters: 648
3) Number of nonlinear parameters: 26
4) Total number of parameters: 674
5) Number of training data pairs: 1620
6) Number of testing data pairs: 648
7) Number of fuzzy rules: 108

8) Error tolerance: 0.0001

The initial membership functions corresponding to each of the inputs is as shown in the figure 4. Once the ANFIS structure is created and initial membership functions are ready, the ANFIS system is now trained for the number of epochs so as to get the least error and the optimized results. After training is completed the system is tested for the testing data loaded.

In our system the data is trained for 300 epochs. The average training and testing errors obtained for 300 epochs are 0.15571 and 0.24688 respectively.

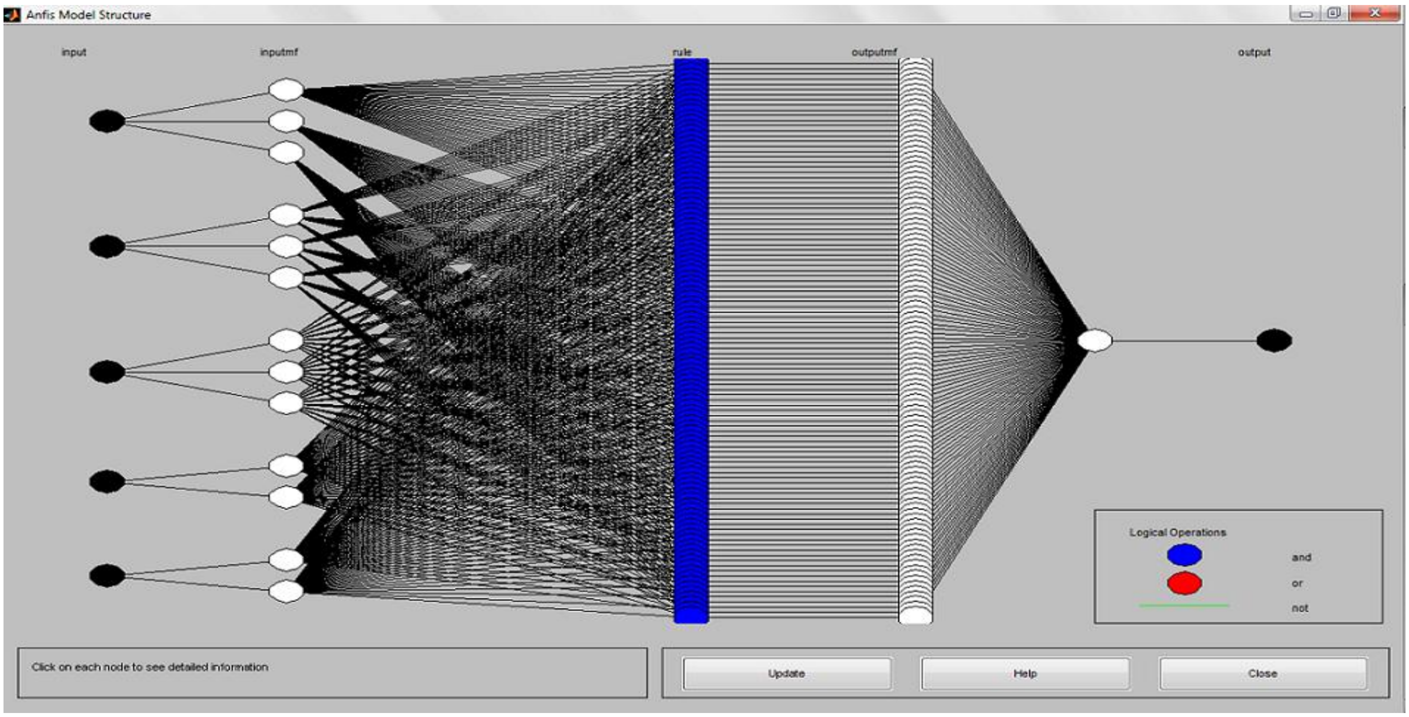

Figure3. ANFIS model structure

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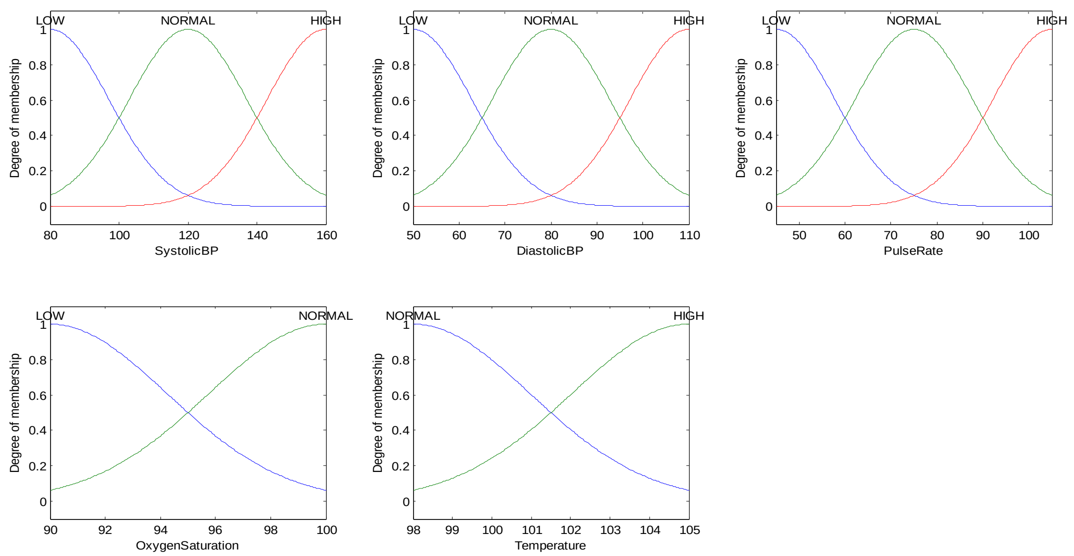

Figure4. Initial membership functions before training

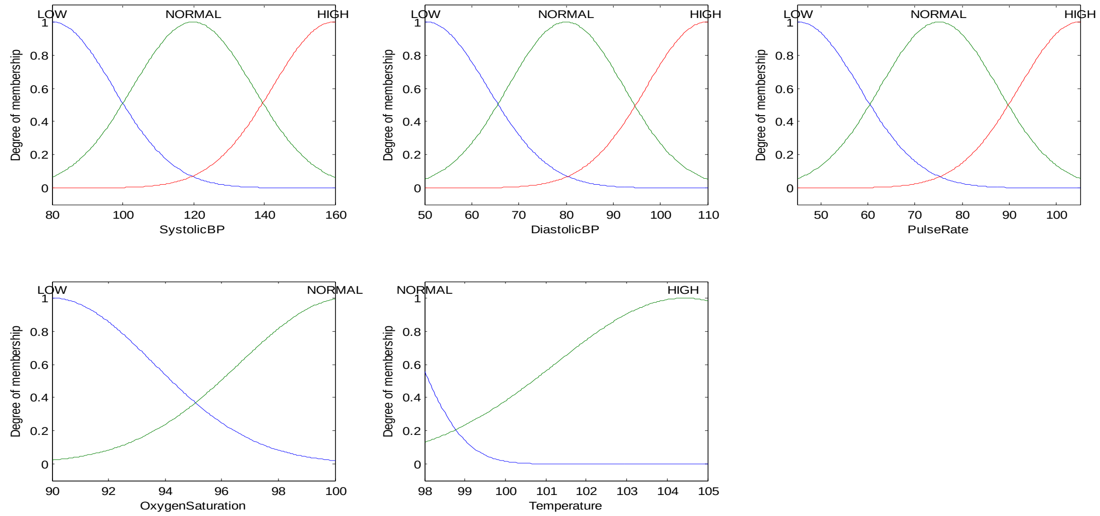

Figure5. Final membership functions after training

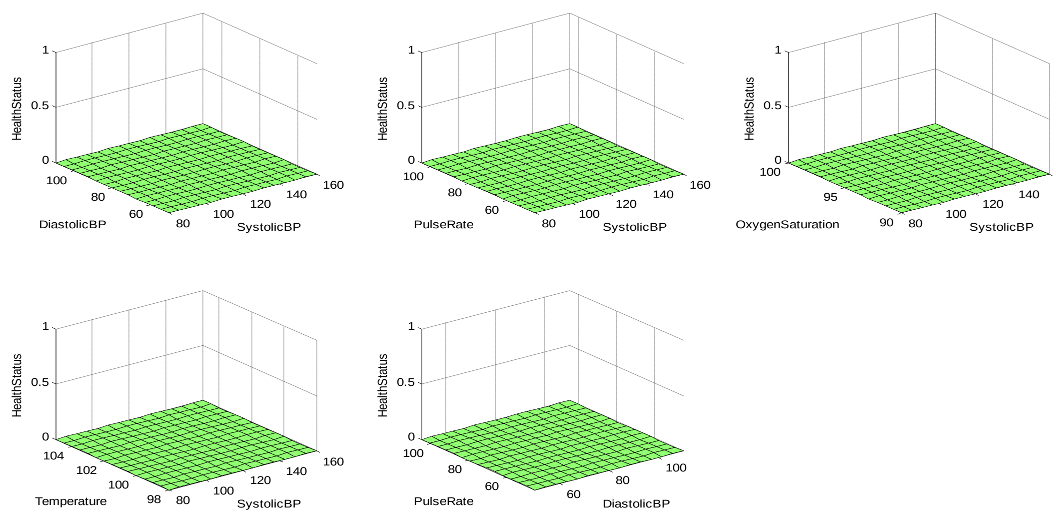

Figure6. Initial surface plots before training

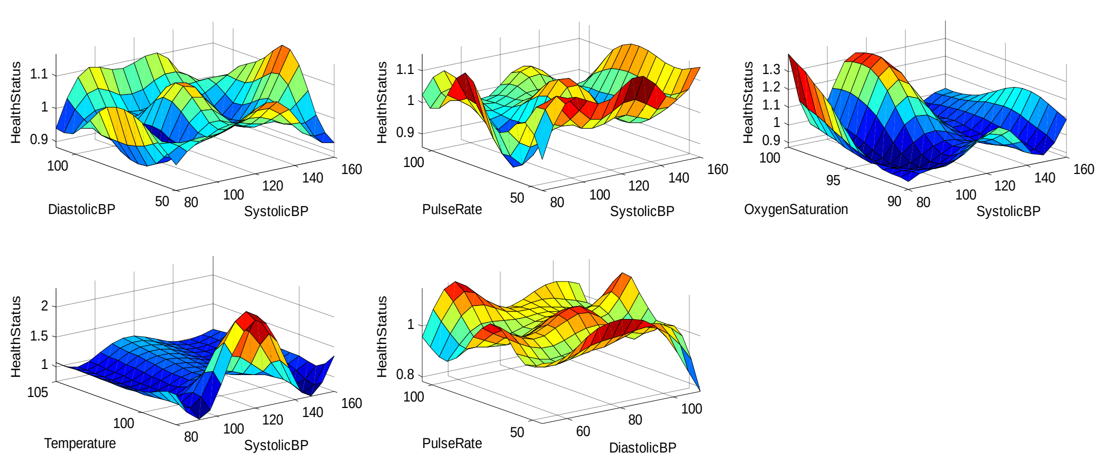

Figure7. Final surface plots after training

During the process of training the initial membership functions associated with each of the inputs undergo changes and shift in their position. This shift in membership functions in one way indicates that the system has undergone appropriate training. The final membership functions obtained after training are as shown in the figure 5. Similar to the membership functions the surface plot between inputs and output is different before training and after training the ANFIS system. This can be easily understood by comparing both the surface plots. Figure 6 and Figure 7 shows some of the surface plots before training and after training respectively.

V. CONCLUSION

This paper introduced the initial attempts for remote health monitoring using Adaptive Neuro-Fuzzy Inference System adaptive learning mechanism. The performance of ANFIS was evaluated by diagnosing number of patients under the supervision of a medical practitioner in a private healthcare centre. After comparing the results obtained from the developed system and the opinion of the physician it was found that the ANFIS system proved to be satisfactory with the minimum training error of 0.15571. The ANFIS approach has successfully solved the problem of incompleteness in the fuzzy rule base made by the human expert. Hence, the system can be used effectively for home health monitoring. Future research could be to monitor the health of patients on a continuous, regular and real time basis. The developed healthcare system will thus be useful for the elderly and terminally ill patients confined within their homes and at the same time helpful to the pregnant women for their regular checkups without personally visiting to the clinic.

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