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Human Heartbeat and Blood Pressure Monitoring using Fuzzy Controllers

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Abstract - *The Biological systems are highly non-linear, and there is a significant amount of variability in the results from one patient to another. It is observed that High Blood Pressure is a major health issue in today's World. The human body, particularly the cardiovascular parameters are significantly ill impacted by longer bed rest. Using Fuzzy controller and Fuzzy logic helps to overcome this negative impact and to enhance functional recovery. The nature of the cardio-vascular system is time-variant and non-linear. Here a self-learning adaptive fuzzy controller is used. This fuzzy controller has an intelligent structure and does not require any prior knowledge about the patient and about the range of cardiovascular parameters. This fuzzy controller manages the body's inclination for adjusting the blood pressure and heart rate as the inclination can increase and decrease the cardiovascular parameters. This helps to maintain the cardiovascular parameters which can enhance the recovery of the patient and make the patient active in lesser time. Here the goal is to mobilize the patients faster maintaining their blood pressure and heart rate using fuzzy logic.*

***Key Words*: Blood Pressure, Cardiovascular, Fuzzy Controllers, Heart Rate, Self-learning**

1. INTRODUCTION

Many Patients after a stroke require intensive care, and they face prolonged bed rest. Having a bed rest for a longer time period have a negative impact on the cardiovascular system as the values does not remain stable in the safer range and this can significantly delay the recovery. Early mobilization using fuzzy controllers helps to accelerate the recovery in these patients. The cardiovascular parameters are very crucial for making the patient active and to regulate the normal functioning of the human body. Controlling these parameters can avoid severe adverse effects. Here the self-learning fuzzy controller having a single input and single output controls the blood pressure and the heart rate of the body via the stimulus of "body tilting". Here a more predictive and accurate model is used that does not require an identification phase or any detailed prior knowledge. This helps the controller to adapt to the frequent changes in the human body response in the real time irrespective of weight, height, and other physical parameters. The controller adjusts the cardiovascular parameters such as heart rate and the blood pressure (either increases of decreases) through body's inclination and brings it back to the safer range.

In [1] the deterministic learning model was used to for the inputs and then the model checks the output from the patient's real time observations and provides the input directly to the controller. The model used the reinforced approach to regulate the heart rate and blood pressure. In [2] the feature extraction technique was used which resulted in better neural network systolic and diastolic blood pressure estimator and it was found that the performance was very efficient with respect to the generalization, computation of the prediction and control when compared to other existing methods. Here a feed forward neural network consisting for more than one layer was used. The supervised learning technique of back-propagation was used for the neural network in the learning phase. The distribution studied in this paper was gaussian/normal distribution. In the [3] authors used SNP (Sodium Nitroprusside) it is a very fast action drug which helps to lower the blood pressure very fast as compared to any other drugs. The negative point of using SNP is that the excess dose of the drug can be fatal, so it must be used carefully. The Fuzzy controller was used to monitor the rate of the real time blood pressure and the value of SNP to be infused. It was found that the simple fuzzy controller used was able to control and regulate the real time blood pressure of the human body within short period of time. The mean arterial pressure was considered to be the criteria for implementing the process on the patient. The infused drug rate was found to be the output of the system whereas the errors and change in errors were given as the input to the fuzzy controller. It was found that when the system was run initially the values were high but after successive runs the fuzzy controller was found to adapt itself and the values were observed to be in the required range. The tests were implemented in stable and simulated environment which was made available using the computerized virtual setting. This controller with adaptive ability was found to outperform the other two controllers, the other two controllers were observed to contain few amounts of oscillation error in the target value which caused the poor performance of the controllers. In [5] a new model of fuzzy controller with self-structuring abilities was proposed. The main aim of the method used here was to provide a way to make the fuzzy controllers adapt when no prior information is available about the subject. In [6] the authors proved the need of fuzzy controllers to have a good performance over a wide area of practical problems. The wide variety of fuzzy membership functions and graphs were proposed. The importance of defuzzification for approximating any real continuous functions with accuracy was proved. In [7] the authors proved that the nonlinear advanced control technology allows to design a non-switching and stable solution to control the heart rate problem after rigorous exercise. It was also proved that the system can be modified with the non-model-based abilities which can be used for better performance. The heart rate regulation was done for treadmill exercise by adjusting the speed of the treadmill based on the error calculated. A system to monitor the heart rate response, that is the increase in the heart rate while exercising which have a non-linear nature was introduced in [8]. The non-linear model used was having a feedback and feedforward components present. In [9] the authors designed a fuzzy controller for linear model to achieve better and improved tracking performance. The various strategies for regulating the blood pressure and to control it were thoroughly reviewed in [10]. Various strategies based on optimization, adaptation and rule-based controllers were also put forward and discussed in [10].

Here we use the self-adapting fuzzy controller is used to monitor and to control the variance in the blood pressure and heart rate of bed ridden patients. The nervous system in the human body is responsible for controlling the cardiovascular parameters such as heart rate and blood pressure. The longer bed rest leads to longer recovery duration as well as post recovery problems. Fuzzy controllers are used to monitor these parameters in patient's body. The parameters must be in a safe range and must be controlled very efficiently, also longer bed rest may lead to stress conditions which can lead to rise in blood pressure level and exceeding out of safe range. SNP (Sodium nitroprusside) is a drug that can be used to control the high level of blood pressure. But excess amount of SNP can be fatal. The safe level of SNP infusion can be monitored by using fuzzy controller. This combined can help patient mobilize faster and can reduce the chances of negative effects of longer bed rest.

2. TECHNOLOGY USED

The Figure-1. shows the self-learning mechanism of the fuzzy controller used in the paper learning from the previous results. The learning algorithm is used along with the reference model so that the controller can adapt from the past experiences.

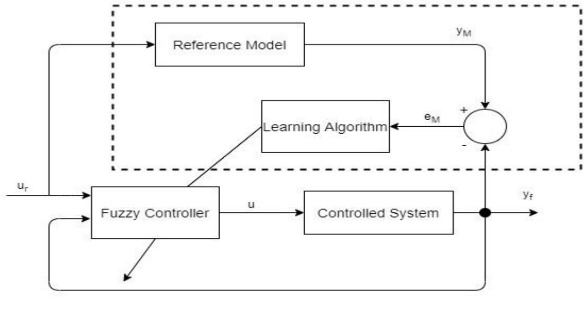

Figure-1: Self-learning Mechanism of Fuzzy Controller

The Fuzzy controller is used instead of the other controllers as the fuzzy controllers can be used to express the pattern that cannot be classified directly into true or false. Also, in this paper the fuzzy controller tends to learn from the previous experience which reduce overall error and, increase the accuracy and the efficiency of the system from time to time.

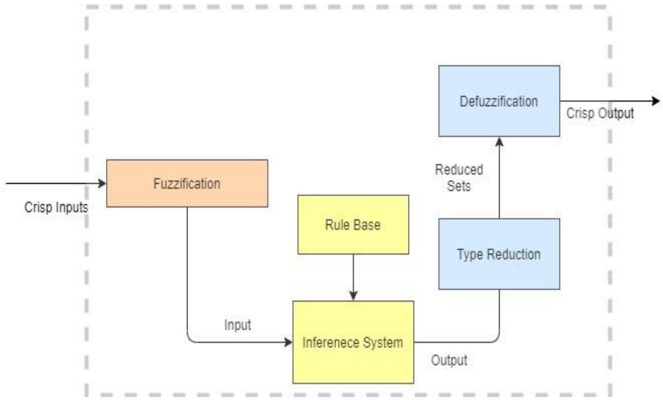

Figure-2: Fuzzy Inference System

The Figure-2. shows the fuzzy controller inference system used in the paper. The Fuzzification and the Defuzzification processes are shown in the diagram. The crisp inputs which are the raw inputs are converted into the fuzzy inputs for the processing which are given to the inference system and the fuzzy output obtained from the inference system of the fuzzy controller is again converted back to the human understandable crisp outputs.

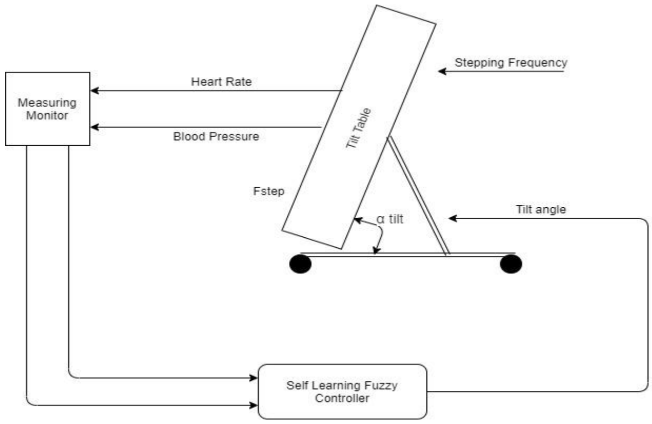

Figure-3: Robotic Tilt Table with connected Fuzzy Controller

The Figure-3. Shows the tilt table connected to self-learning fuzzy controller used for controlling the inclination of the patient. The inclination of the patient's body helps in changing the blood pressure and heart rate. The fuzzy controller with single input end and single output end is used and the values of the real time heart rate and real time blood pressure are controlled using the inclination of the tilt table. The controller used in the paper uses self-learning mechanism which learns by the experience with the patient and tries to improve itself after every action the controller performs. The inclination angle of the table is always maintained between 0 to 75-degree. It is observed that whenever there is irregularity in the values of the cardiovascular parameters, the tilting bed changes the angle by movement and the parameters are brought back to normal levels. The monitor used in the paper requires a small calibration, blood pressure is measured using the arm and for measuring the heart rate the meter is connected to the tip of the fingers. These signals in form of analog waves were given as an input to the bed PC. The real-time values of BP were computed by taking the average of peak signals. The length between the BP peaks in real-time was averaged to calculate the heart period. For each patient two to three experiments of HR, systolic BP and diastolic BP control were recorded. To calculate steady state, cardiovascular parameters were averaged. In case of controlling the cardiovascular parameters, it is found that tilting often results in an increase of Heart rate and diastolic BP in healthy subjects and systolic BP either increases or does not change.

A real-time system for measuring cardiovascular parameters is difficult to model due to the non- linear and constantly changing nature of the parameters. The self-adapting fuzzy controller is used which does not require any knowledge about the patient and the parameters to control it continuously adapts itself to the process. A simple zero-order fuzzy controller was used with the intelligent self-learning abilities which is the combination of fuzzy logic and the reinforcement learning.

The total error between the Blood Pressure and the real time heart rate was calculated mathematically and it was considered for the learning phase of the controller. Three fuzzy membership functions were used to define the mechanism of the controller, they were "negative", "positive" and "zero". The defuzzification is done by using the multiplication of the errors as T-norm and the weighted average of the errors calculated is also used in combination. It is found that the tilting does not have any negative effect on the other parameters in the patient's body. Some cardiovascular parameters were found to increase in the controlling phase. Also, it was found that all the parameter were brought to the safe range so that there is no adverse effect on the body of the patient. The learning factor of the controller was given by the ratio of the changes in the input variable and the changes in the output variable. The noise frequencies were filtered so that the performance of the controller over a longer run is not affected.

It was found that the systolic BP is very little affected by the process but the values of diastolic BP and the heart rate are significantly increased or decreased and they are found to be eventually stabilized in case of all the patients. The fuzzy controllers are very much sensitive to smaller changes and therefore are the most reliable in the field of medical science.

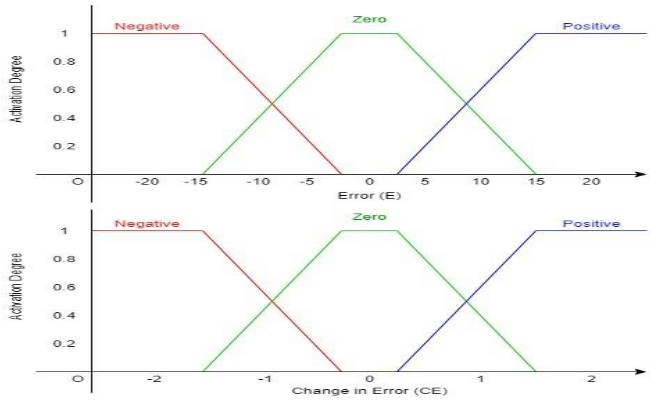

Figure-4: Membership Graph for Error Calculation

3. CONCLUSIONS

The standard deviation and the average errors in systolic BP, diastolic BP and heart rate among the subjects showed that the controller performance shows that the controller was able to reach the desired values efficiently in less time. This shows that the controller is highly accurate and robust in the terms of performance. The early mobilization in patients using self-adapting fuzzy controller can reduce the negative impacts of prolonged bed rest by monitoring and controlling the cardiovascular system. Cardiovascular parameters are naturally controlled by nervous system. Impairment of this control system is very common in bed ridden patients and this make early mobilization of patients difficult. The self-adapting single input-output (SISO) Fuzzy controller can control the parameters like blood pressure (Systolic and diastolic) along with the heart rate through inclination. Also, the advantage of this controller is that it does not require previous experience and learn with successive implementations. These parameters are required to be in safe range for patients, also long bed rest may lead to stressful conditions which can affect the recovery of the patient. The fuzzy controller detects the blood pressure level and when it exceeds the safe range the controller regulates the blood pressure by the infusion of required safe amount of SNP (Sodium Nitroprusside). This reduces the high blood pressure and is very effective for faster recovery of the bed ridden patient. For further advancement we can use fuzzy controller based on neural networks, which can be integrated with the patient's nervous system. This will make the system more efficient and accurate as the value of natural cardiovascular parameters will be available to the controller and the system can be trained using reinforced or unsupervised learning models.

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BIOGRAPHIES

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