CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

Intelligent systems have appeared in many technical areas such as consumer electronics, robotics, industrial control systems and medical systems. As the real world knowledge is characterized by incompleteness, inaccuracy and inconsistency, many of these intelligent systems are based on fuzzy control strategies which describe complex systems mathematical model in terms of linguistic variables (Linkens et al, 1998). The current application area of control engineering in medicine constitute a wide spectrum ranging from simple dosage prescription schemes to highly sophisticated adaptive controllers. Although there are many devices available for cardiac and renal problems, no specific controller is designed for controlling the risk factors of the disease which in turn automatically maintains the variation of risk factors always at normal level.

In this research work, a design methodology of a controller is proposed to identify the existence of uncertainty in the risk factors which affect cardiac and renal of the Diabetes Mellitus patients and to predict the stages of cardiac as S1, S2, S3 and S4 based on Heart Beat Rate and stages of renal as S1, S2, S3, S4 and S5 based on Glomeruler Filtration Rate. Rule viewer in MatLab is used to test the fuzzy rules and to know the aggregated crisp value. Surface view is generated to map the variations in the input and output variables.

A fundamental logic circuit is designed to monitor the related variations of the seven risk factors and to know the stages of cardiac and renal. The circuit takes any variations of seven risk factors as defined in the fuzzy sets as inputs and the first level of logic circuit output produces the range where the specified input values fall. The second level of output produces the stages of cardiac and renal based on the first level output. A simulated model is designed using Simulink to simulate the proposed controller which identifies the risk factors and predicts the stages of cardiac and renal of Diabetes Mellitus patients.

Fuzzy Inference System is automatically generated while training and testing the data. It is used to know the output value based on the rules fired. Fuzzy c means clustering

is used to group the patients scattered data according to the risk level, which helps the medical expert to decide which patient has to be given priority for the treatment.

Thus, the proposed controller is completely a different and flexible approach using Fuzzy Logic which easily captures the patient's risk factors and predicts the different stages of cardiac and renal. This controller is very much useful for the medical experts to predict the disease at right time and to give proper treatment which ultimately reduces the mortality rate.

4.2 Performance Evaluation of the proposed controller to normalize the results based on errors within the Universe of Discourse

The performance evaluation of the proposed controller is done for cardiac arrest and renal failure of Diabetes Mellitus Patients to identify the value required for error correction as output and error, change of error as input to control and monitor the risk factors without any error. The error may occur while diagnosing, treating, observing and examining. The required correction in the process output must be related to changes in the process input as well as the control output. The error 'e' equal to the set point minus the process output and change of error 'Δe' is equal to the error from the process output minus error from last process output. The investigation of the performance evaluation of the proposed controller for cardiac arrest and renal failure with Diabetes Mellitus is carried out using MatLab. The following graph shows the change in value of the risk factors based on the range defined in the membership function for fuzzification and defuzzification as Linguistic Variables. Frequent modulation of risk factors may be watched during diagnosis and treatment to identify the risk level of the patient. Figure 4.1 shows the frequency of change of risk factors.

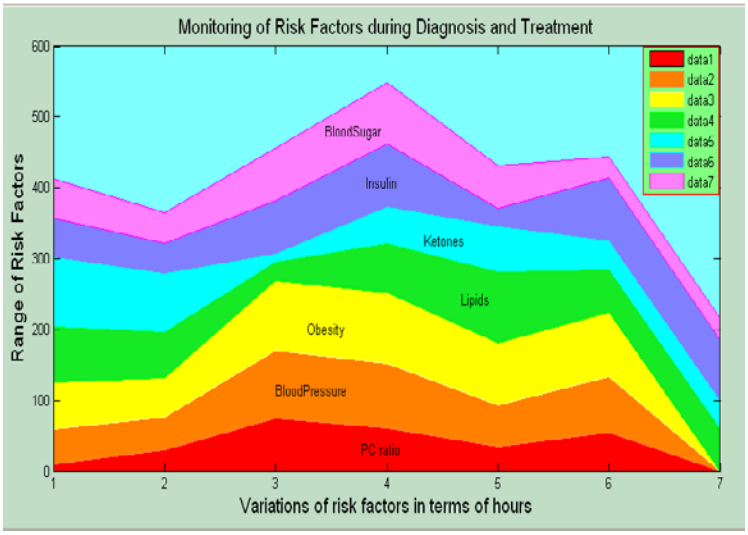


Figure: 4.1 Frequency of Change of Risk Factors

The performance evaluation of the fuzzy logic controller to investigate the serious illness of the patient is verified using MATLAB. The structure of Fuzzy Inference System for detection and correction of error is shown in figure 4.2.

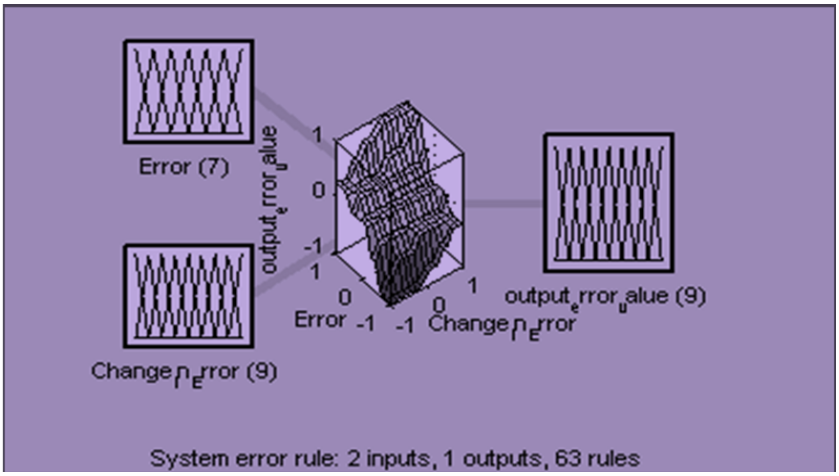


Figure 4.2 Structure of FIS for detection and correction of error

Assumptions

- All Universe of Discourse are normalized to lie between -1 and 1 with scaling factors external to Fuzzy Logic Controller used to give appropriate to the variables.
- It is assumed that the first and last membership functions have their apexes at -1 and 1 respectively only triangular membership functions are to be used.

- The number of fuzzy sets is constrained to be an odd integer, greater than unity in combination with symmetry requirement, this means that the central membership function for all variables will have its apex at zero.
- The base vertices of membership are coincident with the apex of the adjacent membership functions. This ensures that the value of any input variable is a member of at most two fuzzy sets which is an intuitively sensible situation. It also ensures that when a variable's membership of any set is certain (i.e) unity, it is a member of no other sets.

4.2.1 Fuzzy Propositions

Fuzzy rule-based approach for modeling is based on verbally formulated rules overlapped throughout the parameter space. They use numerical interpolation to handle complex non-linear relationships. It consists of set of fuzzy propositions and is derived from the medical expert's knowledge. It establishes a relationship between the input and output fuzzy sets. The following is the rule base table which contains all propositions to find the correction of error and to normalize the result within the Universe of Discourse (Derrick.JL et al, 1998).

TABLE 4.1

RULEBASE FOR ERROR VS CHANGE OF ERROR

Δe / e	CHANGE IN ERROR									
E		NB	NM	NS	NZ	Z	PZ	PS	PM	PB
	NB	NB	NB	NB	NB	NM	NM	NS	NZ	NZ
R	NM	NB	NN	NS	NS	NZ	NZ	NZ	NZ	NZ
R	NS	NS	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ
	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
O	PS	Z	PZ	PZ	PZ	PZ	PZ	PZ	PZ	PS
	PM	PZ	PZ	PZ	PZ	PZ	PS	PS	PM	PB
R	PB	PZ	PZ	PS	PM	PM	PB	PB	PB	PB

NB- Negative Big, NM-Negative Medium, NS-Negative Small, NZ-Negative Zero, Z-Zero, PZ-Positive Zero, PS-Positive Small, PM-Positive Medium, PB- Positive Big.

4.2.2 Rule view of Error Correction

The rule view shows the execution of the rule base using MATLAB for identifying the error of risk factors considered for treating the patients. Rule View with defuzzification to represent the change in error to be normalized within the Universe of Discourse is represented in figure 4.3.

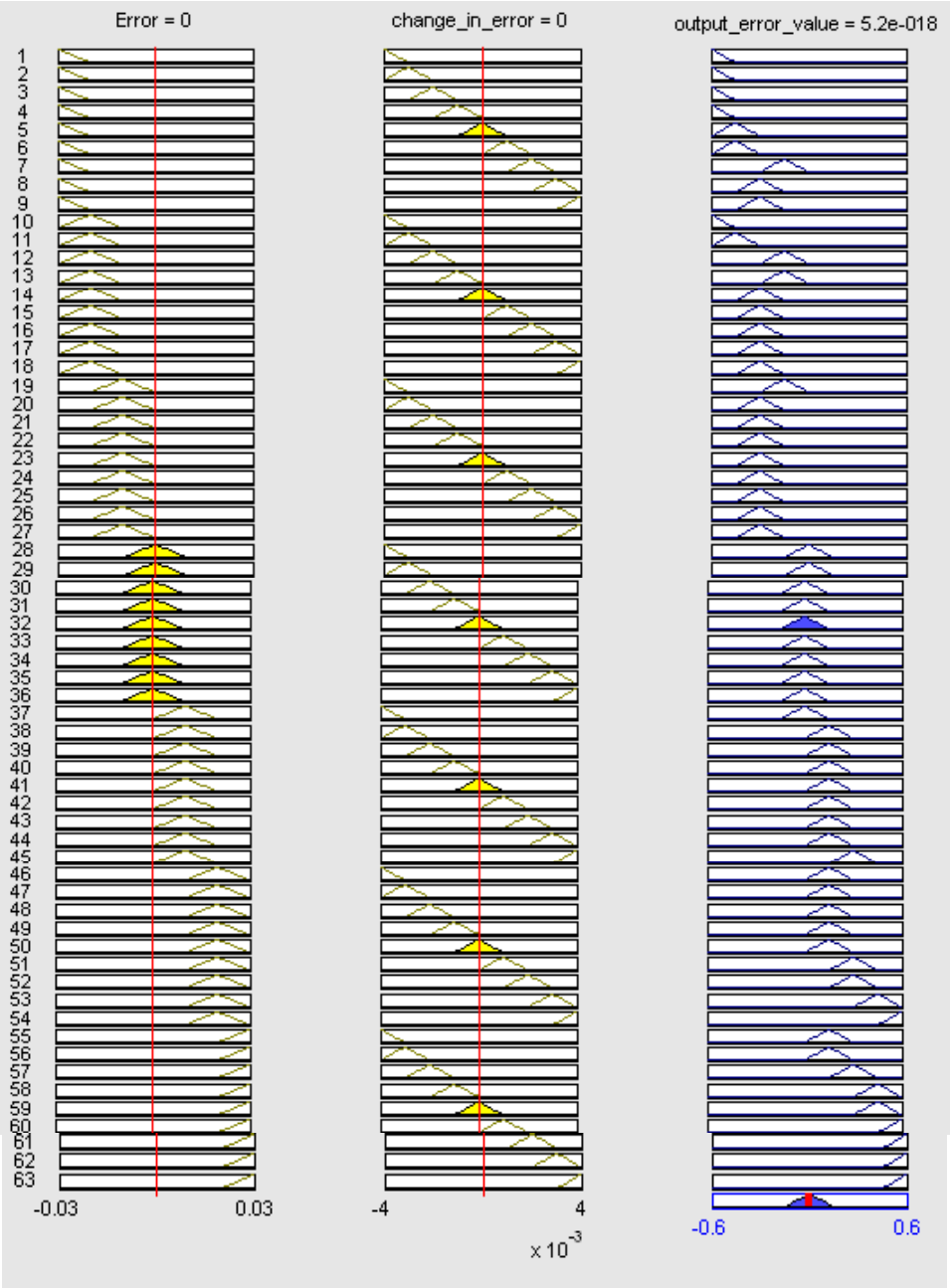


Figure 4.3 Rule View with defuzzification to represent the change in error to be normalized within the Universe of Discourse

4.2.3 Surface View - Correction of error for Diabetes Mellitus

The surface view shows the three dimensional view of the correction of error for diabetes mellitus in which the x-axis represents the error, y-axis represents the change in error and the third dimension z-axis represents the output error value. Figure 4.4 shows the surface view representing the Error, Change of Error and Output_Error_Value.

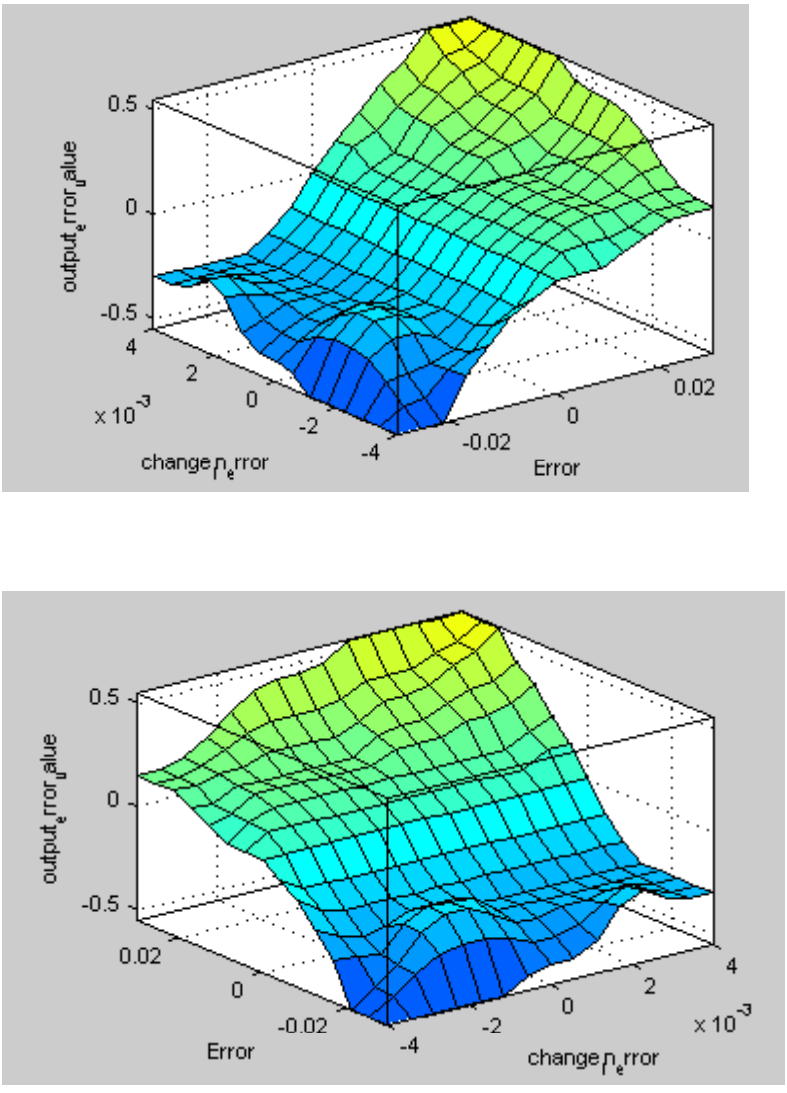


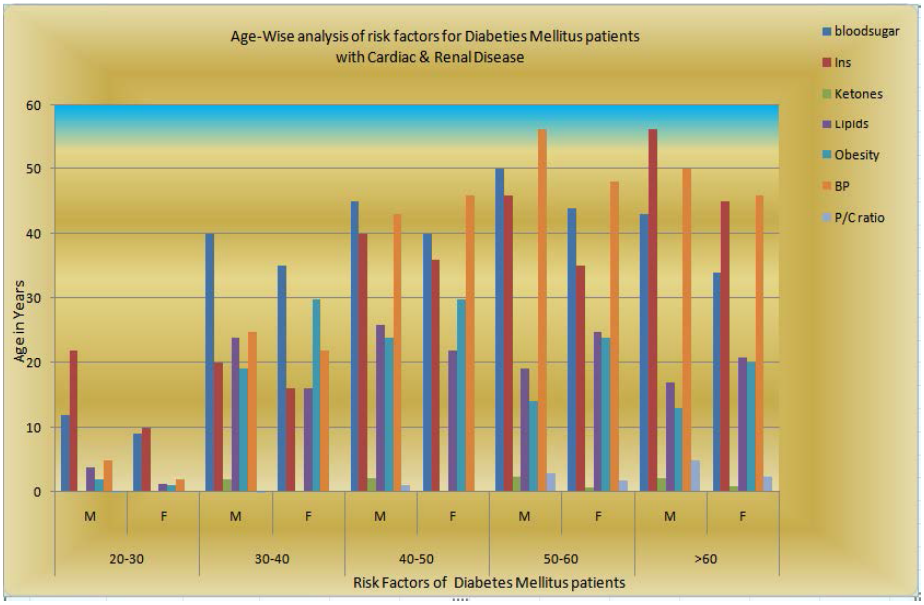
Figure 4.4 Surface View representing the Error, Change of Error and Output_Error_Value

4.3 Clinical Evaluation

Data were collected from "Government District Hospital, Nilgiris" for both in-patients and out-patients. The analysis is based on age, gender and the risk factors considered in this work. The results of the analysis represent the key factors of the disease, prevalence of cardiac and renal problems based on age, sex and the importance of immediate treatment. Table 4.2 represents the analysis of the patient's data with size 334, collected from government district hospital, Nilgiris for both in-patients and out-patients.

TABLE 4.2 ANALYSIS OF THE PATIENTS DATA WITH SIZE 334, COLLECTED FROM GOVERNMENT DISTRICT HOSPITAL, NILGIRIS FOR BOTH IN-PATIENTS AND OUT-PATIENTS

Age in years	Gender	Blood Sugar in percentage	Insulin in percentage	Ketones in percentage	Lipids in percentage	Obesity in percentage	Blood Pressure in percentage	Protein / creatinine in percentage
20-30	M	10-12	17-22	0%	2-4	1-2	3-5	.01-.02
	F	7-9	5-10	0	0.9-1.2	0.9-1	1-2	-
30-40	M	36-40	17-20	1.8-2	18-24	14-19	21-25	.03-.05
	F	30-35	12-16	0	12-16	24-30	18-22	-
40-50	M	40-45	32-40	2.0-2.2	20-26	16-24	39-43	.7-1
	F	37-40	28-36	0	15-22	25-30	42-46	-
50-60	M	43-50	38-46	2.1-2.5	16-19	12-14	44-56	1.2-3
	F	39-44	25-35	.5-.7	20-25	19-24	40-48	.9-1.8
>60	M	36-43	45-56	1.9-2.1	12-17	10-13	42-50	3-5
	F	28-34	38-45	.7-.9	13-21	17-20	39-46	2.0-2.5



Graph 4.1 Analysis of risk factors for diabetes mellitus patients with Cardiac and Renal Disease

Graph 4.1 indicates the analysis of risk factors for diabetes mellitus with cardiac and renal disease. Data were collected from different Diabetes Mellitus patients with cardiac and renal disease. Individual medical record from Government District Hospital, Nilgiris, and Coimbatore were analyzed.

The following inferences are made from the collected data:

- The controllable risk factors vary according to the individuals occupation, life style food habit, heredity, age, gender etc..
- All the seven risk factors are dependent to each other for the cause of renal and cardiac disease especially for Diabetes Mellitus patients.
- Patients with high Blood Sugar have the positive range of ketones.
- Patients with high lipids have elevated Blood Pressure that affects cardiac suddenly.
- Patients with obesity and ketones are found to be few comparing to the other risk factors.
- Diabetes Mellitus patients with cardiac problem and high Blood Pressure are easily affected by renal disease.
- As per the analysis of the samples collected, the patients with Diabetes are easily prone to cardiac and renal problems compared to non-diabetic patients.

- It is found that patients with high blood pressure have the traces of Protein/Creatinine which in turn leads to renal failure.
- It is observed that there is 100% synchoronization exists among all the risk factors.
- Diabetes mellitus patients are found to be less between the age groups of 30 – 40.
- Due to the non-controllable risk factors like age, heredity, sex, the patients with Diabetes Mellitus are found to be more for the age groups between 40 and 50.
- Patients above 40 years of age are prone to severe episodes of hyperglycemia and ketoacidosis.
- 60 percentage of the people have lipid disorders due to the lack of insulin or defects in its action.
- In most of the patients, the LDL levels vary directly with the extent of hyperglycemia.
- About 30-40 percentage of patients develop nephropathy, after 15-20 years of duration of diabetes.
- 20-30 percentage of the patients with diabetes develop the evidence of nephropathy.
- There are no symptoms of Diabetic Nephropathy for the patients who have diabetes for less than five years.
- Hyperglycemia is seen to be the definite risk factor for the development of Diabetic Nephropathy.
- The progression of early nephropathy varies with the Blood Pressure.
- Smoking is also an independent risk factor for essential hypertension.
- In about 25 percentage of patients with type 1 diabetes, the Glomeruler Filtration Rate is exceeding the upper limit of normal.
- Diastolic Blood Pressure correlates with the rate of progression of established Nephropathy.
- Over 90 percentage of diabetes with renal damage have retinopathy.
- The patients with End Stage Renal Disorder often experience an accelerated progression of Diabetic Retinopathy, Diabetic Neuropathy and hypertension.
- Control of Hyperglycemia seems to be very difficult for Diabetic Nephropathy.
- 30 percentage of the diabetic subjects have Coronary Artery Disease after 40 years of age.

- Coronary Artery Disease has distinct male predominance compared to female.
- About 60 percentage of the patients have myocardial infarction before 45 years of age.
- High Density Lipoprotein levels are lower in both sexes in diabetics with Coronary Artery Disease compared to non diabetics.
- All patients are hypertensive at the time of renal failure.
- Hypertension seems to be more prevalent in obese diabetic patients.

4.4 Discussions

In this work, a controller is designed to predict the functioning level of cardiac and renal of diabetes mellitus patients using fuzzy logic which captures the uncertainties in the risk factors. It determines how the risk factors are controlled to safeguard the patient from sudden death. The risk factors used for designing this fuzzy logic controller are very essential. As its values are fixed based on the Universe of Discourse, it gives the efficient clinical result for proper diagnosis and treatment. In order to maintain the uniformity, the Fuzzy Logic Controller is designed based on the common terms of linguistic variables for all the risk factors such as Low, Normal, High and Very High. The controller will predict the nature of the blood flow by identifying the major risk factors in order to avoid the immediate fluctuations of blood sugar. The ultimate aim of this work is to successfully reduce the mortality rate of diabetes mellitus patients with cardiac and renal problems at an early stage.

The design of the fuzzy logic controller is done in two phases. In the first phase, the procedure to design the controller has been given. Major risk factors that affect the diabetes mellitus patients are identified and fuzzy sets are created in order to convert the crisp values to fuzzy values. The excellent feature of this work is the design of rule base with all the possibilities of seven risk factors each with four ranges so that it accurately identifies the patient's conditions on any variation of risk factors. Rules are strengthened to capture the exact rule to fire and the aggregation of values is highlighted. Finally the results are defuzzifed to convert fuzzy results to crisp results.

In the second phase, the designed controller is validated using MatLab. The membership functions are constructed for the controllable risk factors within the defined range Low, Normal, High and Very High. Rule viewer is the important component of this

work which reflects the variations of risk factors and shows the stages of cardiac and renal for the given input values. In order to know the variations of any two risk factors with respect to its output, surface view is generated. The results are promising when compared with the medical expert's knowledge.

Simulated model for the designed fuzzy logic controller is generated using Simulink. Using Simulink, the designed Fuzzy Logic Controller is included as a component to monitor the functioning ability of cardiac and renal. This shows the variations of the risk factors based on the fuzzy logic controller design and reflects the output of cardiac and renal for the given input value. Fuzzy C Means clustering is used to group the scattered patient data to high risk and low risk patients. This result is very important because medical experts can categorize the patients for different level of treatment.

The structure of Fuzzy Inference System for cardiac and renal is generated automatically, while training and testing the data. It is used to know the firing of rules and its output is represented diagrammatically. The important feature of this work is the design of basic logic circuit which takes the risk factors as input, process all the rules and produces the stages of cardiac and renal as output. This circuit can be used as a basic circuit for the design of Micro Electro Mechanical System which integrates a large number of systems into a single chip.

The performance evaluation of the controller is measured to find the error correction if any in data while treating the patient. The reason for the cause of occurrence and the complications of controllable risk factors are analyzed based on the sample data collected from the hospital. This analysis is very much helpful for the experts to determine the status of the disease and to give proper treatment at proper time.

The designed fuzzy logic controller may be an aid for medical researchers to perform their research on other diseases like cancer, brain tumor, pediatric problems etc. It is used as a significant technology to fill the barrier between the medical domain and the demands with computer. This work may be helpful for the Information Technology researchers to know the design of the controller, how fuzzy logic is efficiently used to avoid uncertainty, how to normalize the result, how to reduce the percentage of error, how to use MatLab to implement the problems and how to take decision in decision support

problems. It is very much helpful for the medical experts to diagnose the patients status of illness at the right time and thereby reduce the rate of mortality to the maximum level.

Limitations

- The study is limited to the development of Fuzzy Logic Controller for Diabetes Mellitus patients, with type1 and type2 only.
- The data analysis is limited to hospitals in and around Nilgiris, Coimbatore District.
- Limited as a problem of non-linear to linear and it is non-invasive.
- Limited to 7 input and 2 output parameters but can be extended to additional parameters.
- The study is limited as a quantitative measure within the Universe Of Discourse.