ABSTRACT

Computational Intelligence has been used to solve many complex problems by developing intelligent systems. It has appeared in many technical areas such as consumer electronics, robotics, industrial control systems and medical systems. During the second half of the 20^{th} century, medical information is stored in computer systems to assist the medical experts. This traditional quantitative approach becomes inappropriate due to the complexity of the medical practice. Professor Zadeh's publication on the 'rule of max-min composition' forms the origin of two important research areas, "fuzzy control" initiated by Sedrak Assilian, Ebrahim Mamdanii in London and "fuzzy relation" introduced by Elie Sanchez in Marseille. As the world of medicine is surrounded by uncertainty, imprecision, lack of information and contradictory nature, fuzzy set theory and its derived theories provide a highly suitable and broadly applicable basis for developing knowledge-based systems in medicine. Fuzzy Logic is quite suitable for medical domain because of its tolerance to imprecision and the way to make machines more intelligent enabling them to reason in a fuzzy manner like humans.

Diagnosis and Prediction of a disease involves several levels of uncertainty and imprecision. There are many threatening disease in the modern society. Among them, Diabetes Mellitus is one of the most dangerous chronic diseases which produces changes in the blood vessels and hence can affect almost every part of the body. It is due to the high level of blood glucose resulting from defects in insulin production, insulin action or both. It causes considerable morbidity and mortality due to micro and macro vascular complications. Depends on the insulin production, Diabetes Mellitus can be broadly classified into Type1 and Type2 diabetes. Chronic elevation of blood glucose, even when no symptoms are present to alert the individual to the presence of diabetes, will eventually lead to tissue damage, with consequent and often serious disease. The major chronic complications of diabetes mellitus are cardiovascular disease (CVD), nephropathy, neuropathy, amputation and retinopathy. Cardio vascular complication and Diabetic nephropathy are the leading cause of mortality in Diabetic patients.

A risk factor for Diabetes Mellitus is any characteristic that increases the chances of hyperglycemia and hypoglycemia. The risk factors are classified into three major group's namely controllable, non- controllable and contributing factors. Age, sex, heredity are non

controllable risk factors that cannot be changed. Smoking, stress, birth control pills, alcohol are contributing factors that can be changed by an individual. In order to maintain the blood sugar at a normal level, the controllable risk factors are to be controlled according to medical procedure and expertise. As the risk factors are uncertain in nature, fuzzy sets are used to represent them as a membership function defined on the universe of discourse.

Fuzzy logic is a multivalued logic which is similar to human thinking and interpretation. It has the potential of combining human heuristics into computer assisted decision making as it takes into account all the factors and complexities of individuals. Instead of using complex mathematical equations, fuzzy logic uses linguistic descriptions to define the relationship between the input information and the output action. It is well suited to implement control rules that can only be expressed verbally or systems that cannot be modeled with linear differential equations. Rules and membership sets are used to make a decision. Fuzzy logic is based on the way the brain deals with inexact information. It provides an alternative solution to non linear control because it is closer to the real world. Non linearity is handled by rules, membership functions and the inference process which results in improved performance, simpler implementation and reduced design cost.

Fuzzy set theory with its capability of defining inexact medical entities as fuzzy sets with its linguistic approach providing an excellent approximation to medical texts as well as its power of approximate reasoning, seems to be perfectly appropriate for designing and developing computer assisted diagnostic, prognostic and treatment recommendation systems. Fuzzy control provides a formal methodology for representing, manipulating and implementing a human heuristic knowledge about how to control a system.

Fuzzy logic offers several unique features that make it a particularly good choice for many control problems.

- It is inherently robust since it does not require precise, noise free inputs and can be programmed to fail safely if a feedback sensor quits or destroyed. The output control is a smooth control function despite a wide range of input variations.

- Since the fuzzy logic controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can easily be incorporated into the system simply by generating appropriate governing rules.

- Fuzzy Logic is not limited to a few feedback inputs and one or two control outputs nor is it necessary to measure or compute rate of change parameter in order for it to be implemented. Any sensor data that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low.
- Because of the rule-based operation, any reasonable number of inputs can be processed (1–8 or more) and numerous outputs(1-4 or more) generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined. It would be better to break the control system into smaller chunks and use several smaller fuzzy logic controllers distributed on the system , each with more limited responsibilities.
- Fuzzy logic can control non linear systems that would be difficult or impossible to model mathematically. This opens doors for control systems that would normally be deemed unfeasible for automation.

As the rate of mortality increases due to the uncertain fluctuations of blood sugar and its consequences, a Fuzzy Logic Controller is designed for Diabetes Mellitus to predict the stages of cardiac and renal complications. Blood sugar, Insulin, Ketones, Lipids, Obesity, Blood Pressure and P/C ratio are the controllable risk factors considered in this work. Since the diagnosis of disease involves several levels of uncertainty and imprecision, fuzzy logic is used to incorporate the available knowledge into the control system based on the medical experts knowledge and clinical observations. The proposed fuzzy logic controller is validated with MatLab and is used as a tracking system with accuracy and robustness. The controller captures the uncertainty in the risk factors, resolves the cardiac and renal complications with optimum result thereby ultimately reduces the rate of mortality.

The prime objective of this research work is to design and validate a controller for the impact of diabetes mellitus on cardiac and renal using fuzzy logic. Nature of blood flow is predicted by indentifying the risk factors to avoid immediate fluctuations of blood sugar, which in turn controls the heart beat rate and renal function to normal level. This will ultimately control the growth rate of mortality, due to high risk chronic disease – Diabetes Mellitus.

The major contribution of this thesis is the design methodology of the controller in terms of configuration and the validation of the designed controller using MatLab. The controller is designed using four components namely fuzzifier, rule base, inference and defuzzifier. In fuzzification, the crisp values of the risk factors are converted .into fuzzy sets which allow all the input and output to have degree of membership. The membership functions are overlapped to allow smooth mapping of the system. The process of fuzzification allows the system inputs and outputs to be expressed in linguistic terms so that rules can be applied in a simple manner to express the system. Rule base is the back bone of fuzzy modeling. Rules are framed as the composition of IF-THEN format based on fuzzy sets defined with the help of medical expert's knowledge. Using Mamdani Inference Method, the rules are evaluated and aggregated to avoid conflicts. It is used to determine the output value – the stages of cardiac and renal of diabetes mellitus. Finally, Mean of Maximum defuzzification method is used to convert the fuzzy output set to the crisp output.

The designed controller is validated using MatLab as a Fuzzy Inference System within the Universe of Discourse. It includes

- construction of membership function for the controllable risk factors within the defined range Low, Normal, High, Very High.
- construction of rule base in terms of index values represented by a table.
- simulated version of rule viewer which shows the final output value for the given input parameter values.
- surface view shows the variation of the risk factors in terms of three dimensional view.

Simulated model of the controller is generated using Simulink, which shows the functioning of fuzzy logic controller with rule viewer diagrammatically. This model shows the simulated view of the controller in terms of modulating the value of risk factors defined. The groupings of diabetic patients with high and low level of risk based on the risk factors are differentiated with the help of cluster formation. The purpose of clustering is to identify groups of data from a large set to produce a concise representation of a system's behavior. By training and testing the data, using the ANFIS (Adaptive Neuro Fuzzy Inference System) feature of MatLab, the clusters are formed depending upon the size and character, which in turn determines the emergency care of patients. The structure of Fuzzy Inference System for cardiac and renal is generated, while training and testing the data, which is used to know the output value based on the rules. Finally, a logic circuit is designed to test the rules given. It forms the basic circuit design for devising the Micro Electro Mechanical System. The performance evaluation of the controller is measured with the four components to find the correction error if any in data while treating the patient. Based on the sample data, the reasons for the cause of occurrences and the complications of controllable risk factors are also analyzed.