CHAPTER 1
INTRODUCTION

1. Introduction

“Medicine is a science of uncertainty and an art of probability” said William Osler. Medicine is an information-intensive profession. Medical knowledge is characterized by incomplete, inaccurate and inconsistent information. The diagnosis and prediction of a disease is a problem in medicine as it involves several levels of uncertainty, imprecision and it is inherent to medicine. Lack of information, vagueness and the contradictory nature are the common facts of medicine (Angela Torres and Juan J. Nieto, 2006). A single disease may manifest itself quite differently, depending on the patient and with different intensities. A single symptom may correspond to different diseases. In medicine, the principle of "Measuring everything measurable and trying to make measurable that which has not been measurable so far" (Galileo) is still practiced, although its fundamental limitations have been recognized during the course of this century. The traditional quantitative approaches of analysis are inappropriate due to the complexity in the medical practice. Extensive amounts of data stored in the medical databases require the development of specialized tools for accessing the data, knowledge discovery, data analysis, and effective use of stored knowledge. Diagnosis and Prediction of a disease at an early stage becomes a challenge for the medical experts.

The application of computer technology to medicine and health care has benefited humanity on a wider scope. There are many different aspects in which technology is being used to improve the field of medicine. Since uncertainty is inherent in medicine, fuzzy set theory can be considered as a suitable formalism to deal with the imprecision intrinsic to medical problems. Fuzzy logic (FL) is a method to render precise what is imprecise in the world of medicine (Angela Torres and Juan J. Nieto, 2006). It is primarily used as a modeling tool and can help to manage large sets of data while identifying individuals who follow a typical pattern of disease or disease progression. An automated system is much more efficient in processing large amounts from a number of simultaneous sources of data than the manual systems currently employed.
Fuzzy Logic plays an important role in medicine (Abbond MF et al., 2005, Barro S et al., 2002, Boegl K et al., 2004, Mahfouf M et al., 2001, Mordeson JN. et al., 2000, Steimann F. 2001, Szczepaniak PS. et al., 2000). A number of studies are being undertaken evaluating the role of fuzzy logic modeling in medicine. Some of them in which fuzzy logic crosses many disease groups are, to determine appropriate lithium dosage (Sproule BA et al., 1997, Stip E. et al., 2001), to improve decision-making in radiation therapy (Papageorgiou EI. et al., 2003), to control hypertension during anesthesia (Oshita S. et al., 1994), to determine flexor-tendon repair techniques (Johnson M. et al., 2001), to detect breast cancer (Hassanien AE., 2003, Seker H et al., 2003), lung cancer (Seker H et al., 2003), or prostate cancer (Schneider J et al., 2003), to assist the diagnosis of central nervous systems tumors (Belacel N. et al., 2004), to discriminate benign skin lesions from malignant melanomas (Stanley RJ et al., 2003), to visualize nerve fibers in the human brain (Axer H et al., 2003), to represent quantitative estimates of drug use (Matt GE.et al., 2003), to study the auditory P50 component in schizophrenia (Zouridakis G. et al., 1997) and many other areas of application such as to study fuzzy epidemics (Massad E, Ortega NR. et al., 2003), to make decisions in nursing (Im EO, Chee W, 2003), and to overcome electro acupuncture accommodation (Zhu QM et al., 2001).

In the most developing countries like India, people are suffering from lot of threatening diseases due to their life style, profession, economic inability, heredity and many more. Among them, Diabetes Mellitus is one of the most dangerous chronic diseases in the modern society and represents not only a medical but a social problem (Andrei Effimov et al, 2001). It is the root cause for the major complications of any disease which affects the human system that in turn increases the mortality rate day by day. Due to many uncertain risk factors in the domain of Diabetes Mellitus, diagnosing and predicting the complications are hard for medical experts. The natural evolution of Diabetes Mellitus, the obscure nature of diabetic data and the intrinsic ambiguity of diabetic problems require a consistent framework that can handle uncertainty by allowing variable and multiple class memberships and facilitating approximate reasoning. This inevitability makes fuzzy logic a valuable tool for depicting Diabetes Mellitus risk factors by treating them as fuzzy sets.
1.1 Problem Motivation

Diabetes Mellitus represents a spectrum of metabolic disorders which has become a major health challenge worldwide (King, H, 1998). It basically produces changes in the blood vessels and hence can affect almost every part of the body (Lt Gen SR Mehta et al, 2009). Long standing diabetes mellitus is associated with an increased prevalence of microvascular and macrovascular diseases (A. Ramachandran et al, 2002). It is usually insidious and the patient may remain asymptomatic until last stages of the disease.

The prevalence of diabetes is rapidly increasing all over the globe at an alarming rate (Huizinga MM, Rothman RL, 2006). The status of diabetes has changed from being considered as a mild disorder of the elderly to one of the major causes of morbidity and mortality affecting the youth and middle aged people (Mohan.V et al, 2007). It is the root cause of major complications like diabetic retinopathy, diabetic nephropathy and foot ulcer, cardiac and diabetic neuropathy. In India, people suffer from this disease due to over population, economic and environmental conditions and the availability of insufficient medical experts.

High blood sugar can cause damage to many parts of the body, especially kidney and heart. In the domain of diabetes mellitus, smoke, age, heredity, blood sugar, insulin, ketones, obesity, lipids, blood pressure and protein/creatinine ratio are the major risk factors that affect the cardiac and renal of diabetic patients. Since all the risk factors are uncertain, diagnosis of cardiac and renal problem for diabetic patients is hard for the medical experts. Both macro vascular and micro vascular complications cause significant morbidity and mortality among diabetic subjects (Mohan.V et al, 2007).

Even though there are many devices available to monitor and predict diabetes, no specific device is acquirable to predict the complications of diabetes mellitus. As cardiovascular disease and diabetic nephropathy are considered to be the major complications of diabetes mellitus which increases the mortality rate globally, it is proposed to design a fuzzy logic controller to control the risk factors like blood sugar, insulin, ketones, blood pressure, lipids, obesity and protein/creatinine which in turn predict the stages of cardiac and renal.

Since uncertainty dominates medical domain, the proposed controller is designed based on fuzzy logic instead of conventional crisp algorithms. Fuzzy Logic introduces
partial truth values between true and false (Angela Torres and Juan Nieto, 2006). The completeness of fuzzy sets and rule structures guarantee that every data point of the risk factors has a definite response output. So, fuzzy logic is used in this research work to remove the inherent fuzziness of linguistic concepts and uncertain status in Diabetes Mellitus which is the prime cause for cardiac arrest and renal failure.

1.2 Diabetes Mellitus and its Global Prevalence

Diabetes Mellitus is recognized as a group of heterogeneous disorders with the common elements of hyperglycemia and glucose intolerance, due to insulin deficiency, impaired effectiveness of insulin action or both (Harris M, Zimmet P, 1997). Glucose, an important source of energy for the body comes from food. Carbohydrates are the main dietary source of glucose. Rice, potatoes, bread, tortillas, cereal, milk, fruit, and sweets are all carbohydrate-rich foods.

Blood glucose levels are tightly controlled by insulin, a hormone produced by the pancreas. Figure 1.1 shows the structure of pancreas where insulin is secreted. The main function of insulin is to lower the blood glucose level. When the blood glucose increases (for example, after eating food), insulin is released from the pancreas to normalize the glucose level. In patients with diabetes, the absence or insufficient production of insulin causes hyperglycemia. Diabetes is a chronic medical condition, meaning that although it can be controlled, it lasts throughout the life.

Figure 1.1 Structure of Pancreas
The World Health Organization (WHO) in consultation with an expert committee of American Diabetes Association (ADA) has reported the classification of Diabetes mellitus as

- Type 1 diabetes
- Type 2 diabetes
- Gestational diabetes mellitus (GDM)
- Other specific types of Diabetes

1.2.1 Type 1 diabetes

Type 1 diabetes is sometimes called insulin-dependent, immune-mediated or juvenile-onset diabetes. It is caused by destruction of the insulin-producing cells of the pancreas, typically due to an auto-immune reaction, where they are attacked by the body's defense system. The beta cells of the pancreas therefore produce little or no insulin, the hormone that allows glucose to enter body cells.

The disease can affect people of any age, but usually occurs in children or young adults. Type 1 diabetes is one of the most common endocrine and metabolic conditions in childhood. People with type 1 diabetes need injections of insulin every day in order to control the levels of glucose in their blood.

The onset of type 1 diabetes is often sudden and dramatic and can include symptoms such as:

- abnormal thirst and a dry mouth
- frequent urination
- extreme tiredness/lack of energy
- constant hunger
- sudden weight loss
- slow-healing wounds
- recurrent infections
- blurred vision

The incidence of type 1 diabetes is increasing due to changes in environmental risk factors. Environmental risk factors, increased height and weight development, increased maternal age at delivery, possibly some aspects of diet and exposure to some viral infections may initiate autoimmunity or accelerate already ongoing beta cell destruction.
1.2.2 Type 2 diabetes

In type 2 diabetes, the body can produce insulin but it is not enough for the body functions or the insulin does not work properly. This condition is called insulin resistance. The diagnosis of type 2 diabetes usually occurs after the age of 40 years but could occur earlier, especially in populations with high diabetes prevalence. There are increasing reports of children developing type 2 diabetes. Type 2 diabetes can remain undetected, i.e. asymptomatic for many years and the diagnosis is often made from associated complications or incidentally through an abnormal blood or urine glucose test.

Type 2 diabetes is mostly associated with obesity, which itself can cause insulin resistance and lead to elevated blood glucose levels. There are several possible factors in the development of type 2 diabetes. These include:

- Obesity, diet and physical inactivity
- Increasing age
- Insulin resistance
- Family history of diabetes
- Less than optimum intrauterine environment
- Ethnicity

In contrast to type 1 diabetes, people with type 2 diabetes are not dependent on exogenous insulin and are not ketosis-prone, but may require insulin for control of hyperglycemia if this is not achieved with diet alone or with oral hypoglycemic agents. The rising prevalence of type 2 diabetes is associated with rapid cultural and social changes, aging populations, increasing urbanization, dietary changes, reduced physical activity and other unhealthy lifestyle and behavioral patterns.

1.2.3 Gestational diabetes

Gestational Diabetes Mellitus (GDM) is a glucose intolerance of varying degrees of severity which starts or is first recognized during pregnancy. The definition applies regardless of whether insulin is used for treatment or if the condition persists after pregnancy.

Maintaining control of blood glucose levels significantly reduces the risk to the baby as an increased maternal glucose level could result in complications in the baby including large size at birth, birth trauma, hypoglycemia and jaundice. Women who have
had GDM have an increased risk of developing type 2 diabetes in later years. GDM is also associated with increased risk of obesity and abnormal glucose metabolism during childhood and adult life in the offspring.

1.2.4 Other Specific Types of Diabetes

The other specific types of Diabetes are:

- Genetic defects of beta cells dysfunction
- Genetic defects in insulin action
- Diseases of Exocrine pancreas
- Endocrinopathies
- Drugs or chemical induced
- Infections
- Uncommon forms of immune-mediated diabetes and
- Other Genetic syndromes

1.2.5 Diabetes Complications

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. Unsatisfactory metabolic control in children can result in stunted growth. Exposure to both severe hypoglycemia and chronic hyperglycemia can adversely affect neurological development. Children are more sensitive to lack of insulin than adults and are at a higher risk of a rapid and dramatic development of diabetic ketoacidosis which is also called as diabetic coma.

The mechanism by which diabetes leads to these complications is complex but involves the direct toxic effects of high glucose levels along with the impact of increased blood pressure, abnormal lipid levels and both functional and structural abnormalities of small blood vessels.

Diabetic complications may be broadly classified into acute complications and chronic complications (Dr. Deepak Sharma, 2006). The acute complications are commonly the hyperglycemic and hypoglycemic emergencies. The chronic complications are sub classified into micro vascular and macro vascular complications. Micro vascular complications include retinopathy, neuropathy and nephropathy. Macro vascular complications are due to atherosclerosis of large vessels and they include cerebrovascular
disease, coronary artery disease and peripheral vascular disease. While the micro vascular disease is specific of diabetes, the macro vascular disease is not threshold specific but gets accelerated. Figure 1.2 depicts the macro and micro vascular complications with the deleterious progressions of Diabetes Mellitus.

![Figure 1.2 Deleterious Progressions of Diabetes Mellitus](image)

The major chronic complications of Diabetes Mellitus are:

- Cardiovascular disease (CVD)
- Nephropathy
- Neuropathy
- Amputation and
- Retinopathy

**Cardiovascular Disease (CVD)**

Cardiovascular disease is the major cause of death in diabetes accounting in most populations for 50% or more of all diabetes fatalities and much disability. Recent studies in India show that the prevalence of Coronary Heart Disease in Indians may be as high as in the migrant Indians. (A. Ramachandran et al, 2002).
Nephropathy

Diabetes is an increasingly important cause of renal failure and indeed has now become the single most common cause of end stage renal disease, i.e. which requires either dialysis or kidney transplantation. Diabetic nephropathy is one of the leading causes of chronic renal failure in India.

Neuropathy

When blood glucose and blood pressure are not controlled, diabetes can harm the nerves. Digestion and urination, reproduction, and many other functions may be disturbed but the most commonly affected area is the feet and legs. Nerve damage in these areas is called peripheral neuropathy and could manifest in many ways including loss of feeling in the feet and toes. Loss of feeling is a particular risk because it can allow foot injuries which leads to major infections and amputation.

Amputation

Through effects on peripheral nerves and arteries, diabetes can lead to foot ulceration, infection and the need for amputation. People with diabetes carry a risk of amputation that may be more than 25 times greater than that seen in those without diabetes.

Retinopathy

Diabetes can affect sight and cause blindness in several ways. The most common cause of blindness in diabetes is macular edema caused by fluid build-up behind the retina of the eye. A more common complication is background and proliferate retinopathy which can cause blindness as a result of repeated haemorrhages at the back of the eye. Diabetes also increases the risk of cataracts and glaucoma.

1.2.6 Prevalence of Diabetes Mellitus

Diabetes is now one of the most common non-communicable diseases globally. The number of people with diabetes is increasing due to population growth, aging, urbanization, increasing prevalence of obesity and physical inactivity (Sarah Wild, et al, 2004). In order to reduce the mortality rate, it is important to quantify the prevalence of diabetes and the number of people affected by diabetes so that proper planning and allocation of resources can be made. According to International Diabetes Federation,
Global health expenditures to treat and prevent diabetes and its complications was at least USD232.0 billion in 2007. By 2025, this will exceed USD302.5 billion.

Graph 1.1 shows the top 10 countries with the highest number of estimated cases of Diabetes for 2000 and 2030 (Sarah Wild, et al, 2004). India, China and United States are at the top in 2000 and 2030. Bangladesh, Brazil, Indonesia, Japan, and Pakistan also appear in the lists for both 2000 and 2030. The Russia and Italy appear in the list for 2000 but are replaced by the Philippines and Egypt for 2030, reflecting anticipated changes in the population size and structure in these countries between the two time periods.

![Graph 1.1](image.png)

**Graph 1.1 Top 10 countries with the highest number of estimated cases of Diabetes for 2000 and 2030**

Graph 1.2 refers to the number of people with diabetes by age group in the year 2010 and 2030. By 2030, because of the aging of the world’s population, there will be 190 million with diabetes aged 40-59, over 80% of which will be in newly developed or developing countries. There will be almost as many in the 60-79 age groups approximately 198 million (IDF 2009).
Graph 1.2 Number of people with diabetes by age group, 2010 and 2030.

The estimates for 2007 and 2025 showed little gender difference in the number of persons with diabetes. On 2007, there were about two million more women than men with diabetes (124 million women vs. 122 million men), with this difference expected to be about four million by 2025 (192 million vs. 188 million).

In 2007 the number of people with diabetes in urban areas was around 86 million, compared to 66 million in rural areas in countries that are not considered to be established market economies or former socialist economies. By 2025 it is expected that this discrepancy will increase to 179 million urban and 81 million rural persons with diabetes.

According to the World Health Organization, India had 32 million diabetic subjects in the year 2000 and this number would increase to 80 million by the year 2030. The year wise number of diabetic subjects in India is shown in Graph 1.3. The International Diabetes Federation (IDF) also reported that the total number of diabetic subjects in India is 41 million in 2006 and that this would rise to 70 million by the year 2025 (Wild S et al, 2004), (Sicree R et al, 2006).
Graph 1.3 Year wise number of Diabetic Subjects in India

In developing countries, the majority of people with diabetes are in the age group of 45 to 64 years (Sarah Wild, et al, 2004). In contrast, the majority of people with diabetes in developed countries are above 64 years of age. By 2030, it is estimated that the number of people with diabetes greater than 64 years of age will be above 130 million in the world. Graph 1.4 shows the age distribution of the number of people with diabetes in the world.

Graph 1.4 Estimated number of people with diabetes based on age group in the world

India needs to implement the preventive measures to reduce the burden of diabetes as it poses a medical challenge which is not matched by the budget allocations for diabetes care in India. It is estimated that the annual cost of diabetes care would be approximately
90,200 million rupees. The average expenditure per patient per year would be a minimum of Rs 4,500 (Shobhana. R. et al., 2000).

1.3 Diabetes Mellitus and Cardiac

Diabetes Mellitus is an independent risk factor for several forms of cardiovascular disease in both men and women (Dr. Claude Lenfant and Dr. Philip Gorden 1999). The energy source for heart muscle is mostly sugar and fat, and to a lesser degree, protein. Muscles need far more oxygen to process fat than to process sugar. The blood supply to heart muscle comes from large arteries on the outside of the heart. Diabetics have narrowed arteries because high blood sugar levels cause plaques to form and reduce the diameter of the coronary arteries. The increased need for blood flow from burning fat and the decreased blood flow from narrowed arteries put diabetics at very high risk for heart attack, heart failure and sudden death. The increased use of oxygen increases the blood levels of oxidants which lead to the damage of inner linings of arteries. In domain of heart disease risk, smoke, cholesterol, blood pressure, diabetes, sex, and age are main risk factors that affect on heart disease risk. Figure 1.3 shows the heart with muscle damage and a blocked artery due to diabetes mellitus.

![Figure 1.3 Heart with Muscle Damage and a Blocked Artery](image)

The potential risk factors for increased incidence of coronary artery disease in diabetic patients include Lipids, Blood Pressure and Obesity. One third of all deaths
occurring in diabetics after forty years of age have been attributed to Coronary Artery Disease. 75% of subjects sustaining acute myocardial infarction before 45 years of age have some form of glucose intolerance. Smoking, high cholesterol, high blood pressure, stress from social inequality and oppressive work environments, poor diet, high blood sugar and abdominal fat all increase the likelihood of cardiovascular disease events in persons living with diabetes and impaired glucose tolerance. Silent Myocardial Infarction (SMI) is an entity with a greater prevalence in diabetic subjects. The mortality rate due to cardiovascular disease is doubled in diabetic men and quadrupled in women. According to World Health Organization, the projected global coronary heart disease death by sex in 2005 was 47% for women and 53% for men.

![Image of heart problem in various stages](image)

**Figure 1.4 Heart Problem in various stages (cardiac ischemia)**

Diabetes Mellitus can lead to cardiovascular-heart and blood vessel-damage in several ways. When blood flow to the heart muscle is obstructed by a partial or complete blockage of a coronary artery, cardiac ischemia occurs. Figure 1.4 shows the heart problem in various stages. Cardiac Ischemia is a condition in which there is a lack of blood flow and oxygen to the heart muscle. Type 1 and Type 2 diabetic patients have increased cardiovascular risk, especially for coronary artery disease.

### 1.4 Diabetes Mellitus and Nephropathy

Diabetic Nephropathy is the kidney disease that occurs as a result of diabetes (Sarika Arora, 2010). It has become the single most important cause of End Stage Renal
Disorder worldwide. Epidemiological studies have demonstrated that the factors strictly correlated to the progression of nephropathy in diabetic patients are arterial blood pressure, glycemic control, lipid levels, proteinuria levels, obesity, anemia and cigarette smoking with most of this critically influencing mortality (Rossing. K et al, 2004) (Mohanram.A et al 2004). Wastes in the blood come from the normal breakdown of active tissues such as muscles and from food. The body uses food for energy and self-repairs. After the body has taken what it needs from food, wastes are sent to the blood. If the kidneys do not remove them, these wastes would build up in the blood and damage the body.

Figure 1.5 Kidney Cross Section and parts of Nephron

Figure 1.5 shows the kidney cross section and parts of Nephron. The actual removal of wastes occurs in tiny units inside the kidney called nephrons. Each kidney has about a million nephrons. In the nephron, a glomerulus - which is a tiny blood vessel or capillary, intertwines with a tiny urine-collecting tube called tubule. The glomerulus’s acts as a filtering unit or sieve which keeps normal proteins and cells in the bloodstream, allowing extra fluid and wastes to pass through. A complicated chemical exchange takes place, as waste materials and water leave the blood and enter the urinary system. They process about 200 quarts of blood a day to sift out about 2 quarts of waste products and extra water that eventually leave the body as urine.
In diabetic subjects, high sugar levels in the blood can cause the blood vessels to become narrow and clogged. Without enough blood, the kidneys become damaged and albumin (a type of protein) passes through these filters.

Management of traditional risk factors such as hypertension, hyperlipidemia, and smoking to improve cardiovascular and renal outcomes continue to be important in patients with chronic kidney disease. There is, however, growing recognition that nontraditional risk factors such as increased urinary albumin excretion, hypoalbuminemia, elevated serum creatinine levels and/or decreased haemoglobin levels may also be important in individuals with chronic kidney disease.

![Diabetes Affects the Kidney](image)

**Figure 1.6 Diabetes affects the kidney**

The structure and the shape of the kidney which is affected by diabetes is shown in figure 1.6. Excretion of small amount of protein in the urine is called microalbuminuria. The kidney’s filtration function usually remains normal during this period. When kidney disease is diagnosed early during microalbuminuria, several treatments may keep kidney disease from getting worse. Having larger amounts of protein in the urine is called macroalbuminuria or proteinuria. As the amount of albumin in the urine increases, the kidney’s filtration function usually drops resulting in the body’s retention of various wastes (Sarika Arora, 2010). When kidney disease is caught later during macroalbuminuria, end-stage renal disease that is ESRD usually occurs. At this time, the
stress of overwork causes the kidney to lose their filtering ability. Waste products then start to build up in the blood and finally, the kidneys fail. This failure, ESRD is very serious problem. A person with ESRD needs to have a kidney transplant or to have the blood filtered by dialysis. The function of the kidney is best measured by Glomeruler Filtration Rate (GFR).

1.5 Influence of the Risk Factors that mitigate Heart Beat Rate and Glomeruler Filtration Rate

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. 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. In medical system, the normal level of Blood Sugar is from 70/100 mg/dl to 100/140 mg/dl, Insulin is from 12 micro unit/ml to 17 micro unit/ml, Negative values of Ketones, Lipids from 100/200 mg/dl to 130/240 mg/dl, Obesity from 18 to 24 in terms of body mass index, Blood Pressure from 110/75 to 120/80 and the Protein/Creatinine ratio of less than 0.2. Fluctuations from this normal value of the risk factors will cause the fatty deposits on the arteries which ultimately lead to heart problem. It also reduces the glomeruler filtration rate that leads to the different stages of renal problems. In order to identify and predict the risk, the uncertain parameters are constructed as fuzzy input sets and the stages of cardiac and the stages of renal are constructed as fuzzy output sets for the controller. The controller is tested with the set of available knowledge sources and the data collected.

1.5.1 Risk Factors Which Cannot Be Changed (Non-Controllable)

Age – Patients with diabetes mellitus are found to be more for the age groups between 40 and 50.

Gender - Men have a greater risk of Diabetes Mellitus than women do.

Heredity – (Including Race) Heredity plays the major role in the development of Diabetes Mellitus.
1.5.2 Controllable Risk Factors That Can Be Modified, Treated (or) Controlled by Changing Lifestyle (or) taking Medicine.

1.5.2.1 Blood sugar

Diabetes is a disease characterized by abnormal metabolism of blood sugar and defective insulin production. Blood sugar levels are an important parameter for the diagnosis, treatment and prognosis of diabetes (Diabetes Information Hub). It appears to be a much stronger risk factor for the microvascular complications of diabetes than for macrovascular disease.

![Figure 1.7 Excessive Blood Glucose](image)

Blood sugar level is the level of sugar circulating in blood at a given time. Figure 1.7 differentiates normal and excess glucose in the blood. It varies at different times in a day. Some factors that affect blood sugar levels are body composition, age, physical activity and sex. Males and females may also have differing blood sugar levels. Hypoglycemia (low blood sugar) and hyperglycemia (high blood sugar) are the two extreme conditions of glucose levels in our body.

Hyperglycemia or high blood glucose (sugar), is a serious health problem which develops when there is too much sugar in the blood. Two specific types of hyperglycemia are Fasting hyperglycemia and Postprandial or after-meal hyperglycemia.

**Causes and Symptoms of Hyperglycemia**

- Eating too much food, Increased Stress
- Decreased Activity, Strenuous physical activity
Increased thirst, headaches
Difficulty in concentration, blurred vision
Frequent urination, fatigue, weak, tired feeling
Weight loss, blood glucose more than 180 mg/dL

Complications of Hyperglycemia
Vaginal and skin infections, slow-healing cuts and sores
Decreased vision, nerve damage causing painful cold or insensitive feet
Loss of hair on the lower extremities and erectile dysfunction
Stomach and intestinal problems such as chronic constipation or diarrhea
Damage to nerves, blood vessels and other body organs can occur
Ketoacidosis for type 1 diabetes and hyperglycemic hyperosmolar
nonketotic syndrome (HHNS) in people with type 2 diabetes

Hypoglycemia, also called low blood glucose or low blood sugar occurs when blood glucose drops below normal levels. Common symptoms of hypoglycemia include trembling, clammy skin, palpitations, anxiety, sweating, hunger, and irritability. Hypoglycemia can happen suddenly. It is usually mild and can be treated quickly and easily by eating or drinking a small amount of glucose-rich food. If left untreated, hypoglycemia can get worse and cause confusion, clumsiness, or fainting. Severe hypoglycemia can lead to seizures, coma and even death. The range of blood glucose for fasting and post prandial is given in Table 1.1

TABLE 1.1 BLOOD GLUCOSE LEVELS

<table>
<thead>
<tr>
<th>Category of a person</th>
<th>Fasting Value</th>
<th>Post Prandial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum value (mg)</td>
<td>Maximum Value (mg)</td>
</tr>
<tr>
<td>Normal</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Early Diabetes</td>
<td>101</td>
<td>126</td>
</tr>
<tr>
<td>Established Diabetes</td>
<td>More than 126</td>
<td>-</td>
</tr>
</tbody>
</table>
1.5.2.2 Insulin

Pancreas, an organ that is behind the stomach has a group of cells called islet of Langerhans. This islet cells secrete insulin, a natural hormone that controls the level of sugar in the blood. It influences the rates of glucose utilization by the tissues and regulates the storage of the fuel, therefore helps to keep the blood glucose concentration within the normal range (Laleh Kardar et al, 2008). Insulin is the key to unlock the door of the cells to allow the glucose to be transformed from the bloodstream into the cell. Cells cannot utilize glucose without insulin.

The failure to make insulin or insufficiency of insulin is termed as Diabetes mellitus. There are two types of insulin errors that the pancreas makes. The first is type 1 diabetes which produces no insulin. The second is type2 diabetes which does not always produce enough insulin. The pancreatic structure that produces normal and insufficient insulin is shown in figure 1.8.

![Insulin production](image)

**Figure 1.8 Insulin production**

With the type 1 insulin deficiency, our body is in the state of starvation even though lots of food has been taken. This is because without insulin our cells can not be easily opened in order to be able to extract the energy contained in the glucose that came from the food that was taken. This is why the Type 1 diabetics who do not make insulin can become very ill without insulin shots. Insulin is a very very necessary hormone for survival.
Insufficiency of insulin causes the type 2 diabetes mellitus. According to World Health Organization, over 90% of the diabetic cases worldwide is type 2 diabetes. Type 2 diabetes people develop a condition called Insulin resistance. When this happens, the level of insulin in the blood is similar or even a little higher than in normal, non-diabetic bodies. The body’s cell becomes resistant to the insulin almost like type 1 and so it starts to over secrete insulin in order to try to feed its cells. It can become an ever increasing cycle that can escalate out of control. As a result, blood sugar does not get into the cells to be stored for energy. When sugar cannot enter cells, abnormally high levels of sugar build up in the blood. The normal range of serum insulin is 12 micro unit/ml to 17 micro unit/ml. Figure 1.9 shows the role of insulin during high glucose level and low glucose level.

![Figure 1.9 Role of Insulin](image)

Family history and genetics play a large role in type 2 diabetes. Low activity level, poor diet and excess body weight especially around the waist significantly increase the risk
for type 2 diabetes. According to World Health Organization, some of the effects of type 2 diabetes on the body are blindness and visual disability along with heart disease and diabetic foot disease which often ends in amputation of lower limbs. It is also the leading cause for kidney failure. Initial step of defense against type 2 diabetes is diet and exercise. Just half an hour of walking a day will dramatically reduce the risk of developing type 2 diabetes.

1.5.2.3 Ketones

Ketones are an acid remaining in the blood when the body burns its own fat. Glucose is used by cells for energy. But, when there is no insulin to help it transport out of the blood and into the cells, the body has an "energy crisis" and starts to break down body fat into ketones as an alternative fuel source. This is called ketosis. Figure 1.10 shows the ketone productions by the liver.

![Ketone Production by Liver During Fasting Conditions (Ketosis)](image)

**Figure 1.10 Ketone productions by liver**

Ketosis may occur during fasting, after an extended period of exercise or when a high-fat or low carbohydrate diet is followed. It can also happen during an illness when nausea and/or vomiting make it difficult to keep food down.
When ketone levels become excessively high, a condition known as Diabetic Ketoacidosis (DKA) can occur. DKA is an acute, major, life-threatening complication of diabetes (Vasudevan A Raghavan (2011). It is the dangerous complication for people with diabetes when a very high blood sugar level (above 300 mg/dl) is coupled with a severe shortage of insulin in the body (Jean-Louis Chiasson et al, 2003). Particularly affecting people with type 1 diabetes, DKA may also affect those with type 2 diabetes.

DKA is caused due to intercurrent illnesses, pregnancy, inadequate insulin administration, stroke, cocaine use or myocardial infarction. Typical symptoms of diabetic ketoacidosis include:

- Vomiting
- Dehydration
- Deep breathing
- Confusion and sometimes even coma

Symptoms of DKA usually evolve over a 24 hour period with the first sign often being hyperglycemia. Kussmaul respiration - deep, laboured breathing is often a signal to ketoacidosis. Diabetic coma is the most serious symptom of DKA.

A normal test result would be negative, meaning there are no ketone bodies in the blood. Normal value ranges may vary slightly among different laboratories.

**Normal** - negative
**Small** - less than 20 mg/dL
**Moderate** - 30-40 mg/dL
**Large** - greater than 80 mg/dL

### 1.5.2.4 Lipids

Lipids describe an entire class of fats and fat-like substances in the blood. Cholesterol and triglycerides are two types of lipids. Both are waxy or oily in consistency. Blood, on the other hand is watery. Water and oils do not mix. In order for lipids to travel in the blood they must be coated with protein to create a water-soluble package. These packages are called lipoproteins (lipid with protein). Cholesterol is part of the structure of all lipoproteins. By measuring lipoproteins in the blood, excess cholesterol can be detected. Lipoprotein molecules are the packages that transport cholesterol and triglycerides through the bloodstream. They are classified by their size and density. The most well known
lipoproteins are LDL (low density lipoproteins) and HDL (high density lipoproteins). Figure 1.11 shows the cholesterol in the blood stream.

LDL cholesterol is called "bad" cholesterol, because elevated levels of LDL cholesterol are associated with an increased risk of coronary heart disease. LDL lipoprotein deposits cholesterol on the artery walls, causing the formation of a hard, thick substance called cholesterol plaque. Over time, cholesterol plaque causes thickening of the artery walls and narrowing of the arteries, a process called atherosclerosis.

![Cholesterol](image)

**Figure 1.11 Cholesterol in the blood stream**

HDL cholesterol is called the "good cholesterol" because HDL cholesterol particles prevent atherosclerosis by extracting cholesterol from the artery walls and disposing of them through the liver. Thus, high levels of LDL cholesterol and low levels of HDL cholesterol (high LDL/HDL ratios) are risk factors for atherosclerosis, whereas low levels of LDL cholesterol and high level of HDL cholesterol (low LDL/HDL ratios) are desirable.

In type 2 diabetes, quantitative and qualitative abnormalities in lipoproteins are presumed to be responsible for the increased risk of macro vascular disease. Each lipid and lipoprotein fraction is affected by insulin resistance and hyperglycemia (Hulley SB, 1980) (Jeppesen J et al, 1998),
Total cholesterol is the sum of LDL (low density) cholesterol, HDL (high density) cholesterol, VLDL (very low density) cholesterol, and IDL (intermediate density) cholesterol. Different categories of cholesterol level in the human body are given in Table 1.2.

**TABLE 1.2 CATEGORIES OF CHOLESTEROL LEVEL IN HUMAN BODY**

<table>
<thead>
<tr>
<th>Total Cholesterol Level</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 200 mg/dL</td>
<td>Desirable</td>
</tr>
<tr>
<td>200 to 239 mg/dL</td>
<td>Borderline high</td>
</tr>
<tr>
<td>240 mg/dL and higher</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LDL Cholesterol</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 100 mg/dL</td>
<td>Optimal</td>
</tr>
<tr>
<td>100 to 129 mg/dL</td>
<td>Near/above optimal</td>
</tr>
<tr>
<td>130 to 159 mg/dL</td>
<td>Borderline high</td>
</tr>
<tr>
<td>160 to 189 mg/dL</td>
<td>High</td>
</tr>
<tr>
<td>190 mg/dL and higher</td>
<td>Very high</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HDL Cholesterol Level</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 200 mg/dL</td>
<td>Desirable</td>
</tr>
<tr>
<td>200 to 239 mg/dL</td>
<td>Borderline High</td>
</tr>
<tr>
<td>240 mg/dL</td>
<td>High</td>
</tr>
</tbody>
</table>

1.5.2.5 Obesity

The level of weight has become a real burden both medically and socially. Obesity is a condition in which a person has accumulated much more fat than normal and Excess body weight is implicated as a risk factor for many disorders including heart disease, cancer, diabetes, female infertility, high blood pressure, joint pain, back pain, difficulty during pregnancy, kidney and liver problems, breathing problems during sleep,
prostate enlargement, uterine fibroids, gallstone and gestational diabetes etc. Figure 1.12 represents the disorders associated with obesity. The location of fat deposits in the body leads to different risks associated with it. Increased abdominal fat can be estimated by waist size.

Figure 1.12 Disorders associated with Obesity

Obesity plays a central role in the insulin resistance syndrome which includes hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes mellitus and an increased risk of atherosclerotic cardiovascular disease. Body weight and mortality were directly related in the Harvard Alumni Health Study and weight gain is considered as a significant risk factor for development of diabetes mellitus in women. The association of obesity with the insulin resistance syndrome and cardiovascular risk is not only related to the degree of
obesity but also seems to be critically dependent on body fat distribution. Thus, individuals with greater degrees of central adiposity develop this syndrome more frequently than do those with a peripheral body fat distribution.

The different treatment strategies designed for weight loss includes:

**Dietary therapy** - A low calorie diet with a deficit of 500 to 1000 calories/day is recommended for weight loss.

**Physical activity** - Individuals should start moderate activity for 30-45 minutes, 3 to 5 days/week and aim for at least 30 minutes or more of moderate physical activity on all days.

**Behavior therapy** - This is a useful adjunct when incorporated into treatment for weight loss and weight maintenance.

**Pharmacotherapy** - Using FDA-approved weight loss medications in combination with diet and physical activity which results in weight loss when used for 6 months to a year.

**Weight loss surgery** - An option for carefully selected patients with clinically severe obesity when less invasive methods of weight loss have failed and the patient is at high risk for obesity-associated illness or death.

Body Mass Index (BMI) is a simple and widely used method for estimating body fat. The BMI is calculated using height and weight, either in pounds/inches or kilograms/meters: (BMI = kg/m²) or (BMI = lbs*703/inches²). The absolute waist circumference above 102 cm in men and above 88 cm in women or waist-hip ratio above 0.9 for men and above 0.85 for women is also used as measures of obesity. Table 1.3 lists out the heights and obesity points to be maintained in our human body.

Some reasons of obesity includes

- Genetic cause’s obesity runs in some families and requires regular care to avoid obesity.
- Certain medical conditions may cause obesity including hypothyroidism.
- Eating disorders which result in an excessive craving for foods.
- Sedentary lifestyle.
- Sleeping disorders and mental stress.
- People often gain weight when they quit smoking although the effect is usually temporary and the weight returns to normal once the non-smoking habit stabilizes.

**TABLE 1.3 HEIGHTS AND OBESITY POINT TO BE MAINTAINED**

<table>
<thead>
<tr>
<th>Height</th>
<th>Obesity Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.10</td>
<td>1.47m</td>
</tr>
<tr>
<td></td>
<td>143 pounds</td>
</tr>
<tr>
<td></td>
<td>65.0kg</td>
</tr>
<tr>
<td>4.11</td>
<td>1.50m</td>
</tr>
<tr>
<td></td>
<td>148 pounds</td>
</tr>
<tr>
<td></td>
<td>67.3kg</td>
</tr>
<tr>
<td>5.0</td>
<td>1.52m</td>
</tr>
<tr>
<td></td>
<td>153 pounds</td>
</tr>
<tr>
<td></td>
<td>69.5kg</td>
</tr>
<tr>
<td>5.1</td>
<td>1.55m</td>
</tr>
<tr>
<td></td>
<td>159 pounds</td>
</tr>
<tr>
<td></td>
<td>72.3kg</td>
</tr>
<tr>
<td>5.2</td>
<td>1.57m</td>
</tr>
<tr>
<td></td>
<td>164 pounds</td>
</tr>
<tr>
<td></td>
<td>74.5kg</td>
</tr>
<tr>
<td>5.3</td>
<td>1.60m</td>
</tr>
<tr>
<td></td>
<td>169 pounds</td>
</tr>
<tr>
<td></td>
<td>76.8kg</td>
</tr>
<tr>
<td>5.4</td>
<td>1.63m</td>
</tr>
<tr>
<td></td>
<td>175 pounds</td>
</tr>
<tr>
<td></td>
<td>79.5kg</td>
</tr>
<tr>
<td>5.5</td>
<td>1.65m</td>
</tr>
<tr>
<td></td>
<td>180 pounds</td>
</tr>
<tr>
<td></td>
<td>81.8kg</td>
</tr>
<tr>
<td>5.6</td>
<td>1.68m</td>
</tr>
<tr>
<td></td>
<td>186 pounds</td>
</tr>
<tr>
<td></td>
<td>84.5kg</td>
</tr>
<tr>
<td>5.7</td>
<td>1.70m</td>
</tr>
<tr>
<td></td>
<td>191 pounds</td>
</tr>
<tr>
<td></td>
<td>86.8kg</td>
</tr>
<tr>
<td>5.8</td>
<td>1.73m</td>
</tr>
<tr>
<td></td>
<td>197 pounds</td>
</tr>
<tr>
<td></td>
<td>89.5kg</td>
</tr>
<tr>
<td>5.9</td>
<td>1.75m</td>
</tr>
<tr>
<td></td>
<td>203 pounds</td>
</tr>
<tr>
<td></td>
<td>92.3kg</td>
</tr>
<tr>
<td>5.10</td>
<td>1.78m</td>
</tr>
<tr>
<td></td>
<td>209 pounds</td>
</tr>
<tr>
<td></td>
<td>95.0kg</td>
</tr>
<tr>
<td>5.11</td>
<td>1.80m</td>
</tr>
<tr>
<td></td>
<td>215 pounds</td>
</tr>
<tr>
<td></td>
<td>97.7kg</td>
</tr>
<tr>
<td>6.0</td>
<td>1.83m</td>
</tr>
<tr>
<td></td>
<td>221 pounds</td>
</tr>
<tr>
<td></td>
<td>100.4kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body Mass Index (BMI)</th>
<th>Weight Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 18.5</td>
<td>Under Weight</td>
</tr>
<tr>
<td>18.5 --- 24.5</td>
<td>Normal</td>
</tr>
<tr>
<td>25 --- 29.9</td>
<td>Overweight</td>
</tr>
<tr>
<td>30 &amp; above</td>
<td>Obese</td>
</tr>
</tbody>
</table>
1.5.2.6 Blood Pressure

High blood pressure (hypertension) is an important risk factor for the development and worsening of many complications of diabetes mellitus especially the renal disease (V. Viswanathan, 2004). It affects up to 60% of people with diabetes. Having diabetes increases the risk of developing high blood pressure and other cardiovascular problems, because diabetes adversely affects the arteries, predisposing them to atherosclerosis (hardening of the arteries). Atherosclerosis can cause high blood pressure which, if not treated, can lead to blood vessel damage, stroke, heart failure, heart attack or kidney failure. Figure 1.13 shows the shape of the heart due to high blood pressure.

![Normal Heart vs Enlarged Heart](image)

An enlarged heart is a sign that the heart is overworked, often due to high blood pressure.

Figure 1.13 Shape of the heart due to high blood pressure

Blood pressure readings vary but in general blood pressure should not go above 120/80. The first number is the "systolic pressure" or the pressure in the arteries when the heart beats and fills the arteries with blood. The second number is the "diastolic pressure" or the pressure in the arteries when the heart rests between beats, filling itself with blood for the next contraction. The reason for the fluctuations in blood pressure are smoking, eating habits, body weight, improper exercise and salt intake in the diet. A blood pressure of 120/80 or higher is considered high blood pressure in persons with diabetes and chronic kidney disease. Structure of blood vessel due to hypertension is shown in figure 1.14.
The major problems caused by high blood pressure are atherosclerosis (blocking or narrowing of the vessels), stroke, heart attack, heart failure and kidney failure. The American Heart Association has recommended guidelines to define normal and high blood pressure as follows.

**Normal blood pressure**: less than 120/80

**Pre-hypertension**: 120-139/80-89

**High blood pressure** (stage 1): 140-159/90-99

**High blood pressure** (stage 2): higher than 160/100

High blood pressure makes the heart work harder and, over time, can damage blood vessels throughout the body. If the blood vessels in the kidneys are damaged, they may stop removing wastes and extra fluid from the body. The extra fluid in the blood vessels may then raise blood pressure even more and cause severe kidney problems. Table 1.4 represents the blood pressure levels and its different stages.
### TABLE 1.4 BLOOD PRESSURE LEVELS AND ITS STAGES

<table>
<thead>
<tr>
<th>Systolic</th>
<th>Diastolic</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
<td>120</td>
<td>4 - High Blood Pressure</td>
</tr>
<tr>
<td>180</td>
<td>110</td>
<td>3 - High Blood Pressure</td>
</tr>
<tr>
<td>160</td>
<td>100</td>
<td>2 - High Blood Pressure</td>
</tr>
<tr>
<td>140</td>
<td>90</td>
<td>1 - High Blood Pressure</td>
</tr>
<tr>
<td>140</td>
<td>90</td>
<td>borderline high</td>
</tr>
<tr>
<td>130</td>
<td>85</td>
<td>High Normal</td>
</tr>
<tr>
<td>120</td>
<td>80</td>
<td>normal Blood Pressure</td>
</tr>
<tr>
<td>110</td>
<td>75</td>
<td>Low Normal</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
<td>borderline low</td>
</tr>
<tr>
<td>60</td>
<td>40</td>
<td>too low Blood Pressure</td>
</tr>
<tr>
<td>50</td>
<td>33</td>
<td>danger Blood Pressure</td>
</tr>
</tbody>
</table>

#### 1.5.2.7 Protein/Creatinine ratio

Proteinuria is an early sensitive marker of renal damage and it is the most important test for both the initial evaluation and follow up of patients with glomerulopathies (Veronica Verleine Horbe Antunes et al, 2008). Quantization of urinary protein excretion is an important factor for diagnostic, prognostic purposes and to assess the effects of therapy.

The method most commonly used to measure urinary protein relies on 24-hour urine collections which are time consuming, cumbersome, and often inaccurate. To overcome this, the urinary protein/creatinine ratio is used as a single voided urine sample which correlates well with the quantity of protein in timed urine collections. In the presence of stable renal function, a protein/creatinine ratio of more than 3.5 (mg/mg) can be taken to represent "nephrotic-range" proteinuria and a ratio of less than 0.2 is within normal limits. Graph 1.5 shows the protein/creatinine ratio to estimate protein excretion.
Graph 1.5 Protein/Creatinine ratio to estimate protein excretion

This graph illustrates the close relation between total daily urinary protein excretion and the total protein-to-creatinine ratio (mg/mg) determined on the random urine specimen.

**Types of proteinuria**

There are three types of abnormal proteinuria namely glomerular, tubular, and overflow.

- **Glomerular proteinuria** - The proteinuria in glomerular disease is due to increased filtration of macromolecules (particularly albumin) across the glomerular capillary wall. This is a sensitive marker for the presence of glomerular disease.

- **Tubular proteinuria** - Interference with proximal tubular reabsorption, principally due to tubulointerstitial diseases can lead to increased excretion of smaller molecular weight proteins. Tubular proteinuria is not diagnosed clinically since the dipstick for protein does not detect low molecular weight proteins and the quantity excreted is relatively small.

- **Overflow proteinuria** - Increased excretion of low molecular weight proteins can occur with marked overproduction of a particular protein almost always immunoglobulin light chains in multiple myeloma.

Creatinine is a by-product of muscle metabolism. The liver synthesizes creatine which is used as a source of energy by the muscles. About 2 percent of creatine is transformed to creatinine and released into the bloodstream. The kidney filters most of the
creatinine from the bloodstream and eliminates these protein molecules from the body through urination. The urinary protein/creatinine ratio is a useful measure of renal function used in diabetic renal disease.

Proteinuria is recognized as an independent risk factor for cardiovascular and renal disease and as a predictor of end organ damage. In particular, detection of an increase in protein excretion is known to have both diagnostic and prognostic value in the initial detection and confirmation of renal disease and the quantification of proteinuria can be of considerable value in assessing the effectiveness of therapy and the progression of the disease. The National Kidney Foundation has recommended that an increase in protein excretion be used as a screening tool in patients at the risk of developing renal disease. An increase in protein or albumin excretion has been used in the early detection of several specific conditions, for example, preeclampsia, diabetic nephropathy and nephrotoxicity attributable to drugs.

1.5.3 Contributing Risk Factors which can be changed by an Individual
The contributing risk factors that can be changed by an individual are:

**Smoking:** Smoking raises the blood sugar levels and cuts the body's ability to use insulin making it hard to control diabetes. Smoking one cigarette reduces the body's ability to use insulin by 15%. People with diabetes are three times as likely to die of cardiovascular diseases. Smokers with diabetes are more likely to develop nerve damage (neuropathy) and kidney disease (nephropathy).

**Stress:** Stress tends to increase the levels of the hormones like cortical, adrenaline and noradrenalin that can precipitate diabetes in a predisposed individual or worsen it in someone who is already diabetic. Stressful situations raise the heart beat rate and blood pressure which in turn increases the need of oxygen. This need of oxygen brings the chest pain in people who already have heart disease. Stress also increases the amount of blood clotting factors that makes the artery narrowed by plaque and causes heart attack.

**Birth Control Pills:** It contains high level of estrogen and progestin. Taking these pills increases the chances of disease and stroke especially in women older than 35 who smokes.

**Alcohol:** Studies have shown that the risk of diabetes in people using moderate amount of alcohol is lower than in non-drinkers.
1.6 Formulation of the problem and objectives

Effective handling of uncertainty is one of the central problems in the diagnosis and the prediction of the complications of Diabetes Mellitus. As the rate of mortality increases due to the major complication of diabetes mellitus like heart failure and renal disability, a Fuzzy Logic Controller is designed to predict the functionality level of the heart and renal of diabetic patients. The controller performs optimum control on high risk controllable risk factors. This work includes only the controllable risk factors, the non controllable and contributing factors are excluded. The controller considers only the Type1 and Type2 diabetic patients. The goal of the study is to validate the proposed Fuzzy Logic Controller with respect to the domain expert’s knowledge.

- The prime objective is to control the growth rate of mortality, due to high-risk chronic disease – Diabetes Mellitus. Controlling the main seven risk factors attains this objective which affects cardiac and renal of our body.
- The nature of blood flow is predicted by identifying the risk factors to avoid immediate fluctuations of blood sugar which in turn controls the heart beat and renal function to normal level.
- A controller is designed using fuzzy logic to control the controllable risk factors and to capture the uncertainty that happens by acquiring expert’s knowledge, ambiguity by the patient’s description of the disease and occurrence of errors during diagnosis.
- Rule base is constructed based on all seven risk factors with all four ranges of each. This forms the main part of the work because the rule base accepts any combination of risk factors which in turn predicts the functionality level of cardiac and renal.
- MatLab is used to validate the result and the error is normalized and added to the design of the simulated model to reduce the change of error.
- A logic circuit is designed to test the rules which form the basic circuit design for Micro Electro Mechanical System.
- Reasons for the cause of occurrence and the complications of controllable risk factors are analyzed based on the sample data collected.
1.7 *Organization of the thesis*

The thesis is organized into five chapters. **Chapter one** discusses the problem motivation, the need of the work, fundamental and base of the study, threat and prevalence of the Diabetes Mellitus throughout the world as well as in India, overview of the disease, risk factors category, formulation of the problem and objectives. In **Chapter two**, background study about the diabetes mellitus, its prevalence, and utilization of Fuzzy Logic Controller in various fields and in recent research work are discussed.

**Chapter three** explains the formulation of the problem which deals with the purpose and use of the proposed controller. The block diagram of proposed controller is explained in detail. Implementation of the controller with its components is dealt in this chapter with the help of the design presented. Also, this chapter includes the basic logic circuit which can be used for designing the device as micro electro mechanical system. **Fourth chapter** discusses the systematic approach of the components of the controller to validate and implement the proposed design with the collected data and with various constraints. Results are analyzed according to the sample data collected and the procedure for normalizing the error is also discussed to overcome the error. Inferences are presented and the discussions are made in this chapter. **Chapter five** presents the conclusion and the scope for the further enhancement of this research work.