



## Medical Expert Systems for Diabetes Diagnosis: A Survey

**R. P. Ambilwade**

Asst. Professor  
Dept. of Comp. Science  
National Defence Academy  
Pune (M.S.) India

**R. R. Manza**

Asst. Professor  
Dept. of Comp. Science  
Dr.B.A.Marathwada University  
Aurangabad (M.S.) India

**Bharatratna P. Gaikwad**

Research Scholar  
Dept. of Comp. Science  
Dr.B. A.Marathwada University  
Aurangabad (M.S.) India

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*Abstract - Medical expert systems being used for disease diagnosis where the patient's symptoms and other details are inputs and the system diagnose the disease, recommend treatment or drugs which may be prescribed. Medical diagnosis involves several levels of uncertainty and imprecision. This paper reviews the various expert systems used not only for diabetes diagnosis but also gives the treatment and medical advice to patients. The aim of the survey is to determine the current state of research in this area and to help derive the key features and problems with the existing systems. The comparison of the various systems is done on the basis of inputs (data) used for diagnosis, the methodology applied and the platform on which the system is implemented. Most of the diabetic expert system developed diagnoses the Gestational diabetes which is found in pregnant women. The PIMA Indian dataset used for this purpose. Other expert systems used the real time data of patients from hospitals to diagnose the type-2 diabetes. The soft computing methodology is most useful and powerful methodology used for diagnosis purpose. Neural network models, fuzzy system and hybrid-approach such as neuro-fuzzy, ANFIS, PCA are used in many of the systems.*

*Keywords - Expert system, Diabetes, Medical Diagnosis, Diabetic Treatment, Neural Networks, Fuzzy Logic.*

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### I. INTRODUCTION

Diabetes is a leading cause of death in most developed countries, and is spreading rapidly in many developing nations. According to IDF (International Diabetes Federation) diabetes affects more than 140 million people in the world and 50 million people are suffering from this disease in India. [1] It is the most common endocrine disorder in which the body does not produce or properly use insulin.

Expert system is one of the tools used in medical field for diagnosis of diabetes. It is a computer program that provides expert advice or solution as if a real person has been consulted.

Medical diagnosis is a complex and fuzzy cognitive process Uncertainty is an important factor to diagnose a disease. Differentiation of diagnosis that share an overlapping range of symptoms is inherently difficult [2] Doctors use their knowledge, intuition, experience and based on the patients' symptoms, they arrive at an unambiguous result. Diabetes is suspected based on symptoms, risk factors. Blood and urine tests can be used to confirm the diagnosis, based on the amount of glucose found [2][3].

### II. EXPERT SYSTEM

Expert system is one of the application areas of Artificial Intelligence. It can be considered as software, which operates on a sophisticated system like a human expert. It explains their reasoning or suggested decisions, display intelligent behaviour, draw conclusions from complex relationships. [4] The main conceptual source of expert system is knowledge. ES can expand to include a knowledge acquisition component the processes data and information into rules. Expert systems has number of application areas like decision making, prediction, planning, monitoring, process control, forecasting, diagnosis etc.

Medical diagnosis is the major application of. The purpose of medical expert system is to support the diagnosis process of physicians. It considers facts and symptoms to provide diagnosis.

Medical expert system uses knowledge about the diseases and facts about the patients to suggest diagnosis. Medical expert system consists of five major components.[5] 1) *Knowledge base* which contains the specific knowledge related to the area of application of the system. 2) *Database* acts as a working memory and contains current facts or past data. 3) A Rule Base that supports the work with the knowledge to obtain a diagnosis. 4) An Explanation Component making the user knows how the system arrived to suggested diagnosis. 5) User Interface for adequate communication between consulting physicians and the system.

### III. EXPERT SYSTEMS USED IN MEDICAL FIELD

There are several diverse areas in medical field where expert system used successfully. Disease diagnosis of various diseases like cancer, cardio-vascular disease, endocrine diseases, diabetes, tumour, patient monitoring, treatment of illness, prognosis, determining risk of disease, determination of drug dose.[6]

There are several expert systems used in medical field. The MYCIN is one of the earliest rule based expert system developed by Feigenbaum, Buchanan and Ted Shortliffe in 1970 for the purpose of diagnosis of infectious diseases.[7] The diagnosis process involves culturing of the specimens for the isolation and identification of the bacterial infections. This takes 48 hours so doctors had to come up with quick guesses about likely problems. It uses LISP for implementation and consists of 450 rules. MYCIN was good in the sense that it could calculate dosages very precisely and dealt with interactions between drugs.

DENDRAL is the expert system to help chemists in identifying structure of unknown organic molecules, by analyzing their mass spectra and using knowledge of chemistry.[7]

CADIAG-2 [32] (Computer Assisted **DIAG**nosis) is based on fuzzy technology and designed for internal medicine. It is characterized by its ability to process indeterminate (vague or uncertain) information.[8] It supports the medical personnel in interpreting a patient's symptoms, signs, laboratory test results and clinical findings and thereby generating a complete clinical differential diagnosis.

MEDICO is a rule-base system which gives the advice to ophthalmologists about management of chorioretinal diseases. It contains general clinical knowledge and a large data base of facts about previous patients and events. [5]

PUFF diagnoses the presence and severity of lung disease in a patient by interpreting measurements from respiratory tests administered in a pulmonary function laboratory. Various test results and patient history used for diagnosis purpose. It is backward chaining and rule base system developed at Stanford University.[5]

The expert system proposed in [9] is a knowledge management expert system for diagnosis as well as for proper advice for treatment for six diseases Cold, Flu, Cough, Fever, Ear & Eye problems. It represents patients' medical history and present situation into a knowledge base to give consultation effectively. The knowledge is symptoms & treatment/medication collected from physicians. Knowledge representation of this system uses CLIPS, a rule-based language. It provides an environment for the construction of rule and object oriented based ES with Java class JClips.

About 100 patients' records from Hospital database tested with ES. The corresponding results compared to the result of Expert Doctor. The accuracy result of expert doctor is 96% that to of this ES is 91%. There is a scope to expand the knowledge base to include more diseases.

Ali Keles, Ayturk Keles [10] proposed hybrid expert system, ESTDD (Expert System for Thyroid Disease Diagnosis) for diagnosis of two thyroid disorders namely hypothyroidism and hyperthyroidism. It provides assistance for doctors and practitioners for thyroid diagnosis. Thyroid disease is difficult to diagnose due to its overlapping and confused symptoms with other diseases. Three layered feed-forward NN architecture used for this system. First layer represents the input variables, hidden layer uses fuzzy rules and third layer is output layer. NFCLASS (Neuro Fuzzy Classification) algorithm is used for diagnosis which consists of five inputs, twenty rules and three outputs. Data from UCI Machine Learning Repository consists of 3 classes and 215 samples (5 attributes). The ES classification accuracy is 95.35% by 20-fold cross validation. The system is implemented in Visual C# & SQL server as a database platform.

### IV. DIABETES

Diabetes is a metabolic condition that leads to high blood sugar levels. It is a kind of disease in which the body does not produce or properly use insulin. The amount of glucose in blood is too high because the body cannot use it properly. [1] This is because pancreas does not produce any insulin, or not enough, to help glucose enter your body's cells – or the insulin that is produced does not work properly. Insulin is the hormone produced by the pancreas that allows glucose to enter the body's cells, where it is used as fuel for energy so we can work, play and generally live our lives. [11]

#### A. Types of Diabetes

There are two major types of diabetes Type-1 and Type-2. Type-1 diabetes develops when no insulin is produced at all because the insulin-producing cells in the pancreas have been destroyed. Insulin is the key that unlocks the door to the

body's cells. [3] Once the door is unlocked glucose can enter the cells where it is used as fuel. In Type 1 diabetes the body is unable to produce any insulin so there is no key to unlock the door and the glucose builds up in the blood. Type-1 diabetes can develop at any age but usually appears before the age of 40, and especially in childhood.

Type-2 diabetes develops when the body can still make some insulin, but not enough, or when the insulin that is produced does not work properly (known as insulin resistance). Insulin acts as a key unlocking the cells, so if there is not enough insulin, or it is not working properly, the cells are only partially/fully unlocked and glucose builds up in the blood. [12] This type of diabetes usually appears in people over the age of 40. It often appears from the age of 25. It is also increasingly becoming more common in children, adolescents and young people of all ethnicities.

Apart from type-1 and type-2 diabetes, other two types of diabetes are Prediabetes and Gestational diabetes. Prediabetes indicates a condition that occurs, when a person's blood glucose levels are higher than normal but not enough for a diagnosis as diabetes. People with prediabetes have an increased risk of developing Type-2 diabetes. Gestational diabetes mellitus (GDM) arises during pregnancy.[3] [12] It occurs because the body cannot produce enough insulin to meet the extra needs of pregnancy. GDM may be found during the first trimester of pregnancy and the condition most likely existed before the pregnancy.

### **B. Signs & Symptoms of Diabetes**

In Type-1 diabetes the signs and symptoms are usually very obvious and develop very quickly, typically over a few weeks. Symptoms of type-2 diabetes may not be so obvious, as the condition develops slowly over a period of years and may only be picked up in a routine medical check-up. Common symptoms of both types of diabetes includes, Excessive urination, Excessive thirst, Excessive eating, Poor wound healing Infections, Anxiety, Fatigue/tiredness, Weight Loss, Extreme lethargy, Blurry vision etc.[3] There are some risk factors of diabetes such as family history, overweight, high blood pressure, obesity, alcohol or smoking addiction etc.

### **C. Diagnosis of Diabetes**

Diagnosis of diabetes is based on several factors, like patient's physical exam, presence or absence of symptoms, medical history, risk factors, blood reports etc. Blood tests can be used to confirm a diagnosis of diabetes, based on the amount of glucose found. Urine test can also be used to check protein in the urine that may help diagnose diabetes. These tests also can be used to monitor the disease once the patient is on a standardized diet, oral medications, or insulin.[12]

## **V. EXPERT SYSTEMS FOR DIAGNOSIS OF DIABETES**

There are several expert systems developed so far for diagnosis of diabetes. To diagnose the diabetes, it is necessary to have the patient's medical record, symptoms and the reports of various pathological/radiological tests. Most of the expert systems developed so far diagnose the gestational diabetes which is occurred in pregnant women.[13] [14] [15] The dataset used for diagnosis purpose is PIMA Indian diabetes dataset for pregnant women from UCI repository, University of California. There are 8 attributes in this dataset 1) No. of times pregnant, 2) Plasma glucose concentration in oral glucose tolerance test 3) Diastolic BP, 4) Triceps skin fold thickness, 5) Serum insulin, 6) Body mass index, 7) Diabetes pre degree function and 8) Age. The diagnosis is done using different methodologies such as statistical, neural network and fuzzy systems. On the other hand some medical expert systems uses real time patient's data from hospital which covers detail patient information like symptoms, physical examination, risk factors, blood tests for the purpose diagnosis.[16] [17] [18] This paper presents a survey of current research of expert system in diabetes diagnosis and clinical management.

Kemal Polat and Salih Gunes, [13] proposed a diagnosis process in two stages. In first stage, dimension of diabetes dataset that has 8 features is reduced to 4 features using Principal Component Analysis. Classification of diabetes is done using adaptive neuro-fuzzy inference system classifier in second stage. Pima-Indian pregnant women dataset used for this system. Principle Component Analysis (PCA) method is a classifier system used for dimensionality reduction of diabetes disease dataset. PCA is based on the assumption that most information about classes is obtained in the direction along which the variations are the largest. ANFIS is a classifier method to facilitate learning and adaption. It uses fuzzy if-then rules based on a first order Sugeno model. The system gives the classification accuracy about 89.47% by using the 10-fold cross validation. Two classes of classifiers used which is normal & other indicates the diabetes disease. The sensitivity is 85.71%, specificity is about 92% and MSE is 0.262. The benefit of this system is to assist the physician to make the final decision for diagnosis.

In paper [16 ], K. Rajeswari and V. Vaithiyathan proposed the diagnosis method which considers different form of preliminary inquiry information from patients regarding symptoms using fuzzy relational based model (symptom-disease association) The required parameters are modelled using a fuzzy approach and then classified by ANN, as Type-2 diabetes or not. The dataset consists of 600 samples and two classes as normal and Type-2 diabetes. The data are

modeled into 5 stages as general symptoms, complication symptoms, past history, physical examination, feminine questions and lab test measurements. Fuzzification of these features can be done in two stages. First 4 features modelled in stage-1 and remaining 6 fuzzified in stage-2. After fuzzification, a generated vector  $s$  acts as input for NN for classification. The network architecture consists of single hidden layer with 2 input neurons and two output neurons and backpropagation algorithm is used for classification. The method works on real-time dataset and it can assist the doctor for diagnosis. It is not useful for other type of diabetes and does not give the medication or treatment for diabetes.

The methodology proposed in [19] paper, minimizes the patients' various time consuming medical tests and its cost. The diagnosis process is based on basic symptoms & physical conditions of diabetes patients. The input parameters have been designed in such a way that, the user can predict if he is affected with diabetes himself. The inputs for this system are age, gender, family history, smoking or using tobacco products, BMI, waist hip ratio, amount of vegetables & fruit intake, blood pressure, life style (like sedentary work, labour class, retired person, housewife), physical activity. The inputs values are normalized using log sigmoid activation function, before giving to neural network model. Data of 75 patients were collected for the proposed work. The network model consists of 16 input layers (i.e. 16 symptoms), 17 hidden layers and 1 output layer contains one neuron which has value either 0 (no diabetes) or 1 (diabetes). For training network back propagation algorithm is used.

Radial Basis Function neural network is used for diabetes diagnosis. It is based on supervised learning. Data of 1200 patients collected from private hospital used for network model. [17] Fasting Plasma Glucose & Post Glucose values are used as selection criteria for classifying diabetic patients. The risk factors considered are age, gender, BMI, HDL, LDL, family history of diabetes etc. A dataset of 600 another individuals from another specialty hospital was used to validate the model externally. The RBF network consists of single hidden layer with Gaussian RBF. Multilevel Perceptron (MLP) network architecture uses single hidden layer with sigmoid activation function. A back propagation algorithm based on conjugate gradient optimization technique was used to model MLP for the dataset. A logistic regression model was fitted using the input vector & diabetic status as the binary dependent variable. The performance of the above 3 models was evaluated using sensitivity, specificity & correct prediction.

Expert system proposed in [20] uses hybrid expert system for diagnosis of 4 types of diabetes namely, Type-1, Type-2, Diabetes Mellitus in pregnancy & Secondary diabetes. The diagnosis process starts with gathering patient's subjective & objective data (such as lab tests). Decision tree is used for diagnosis. The ES uses PC-Shell 4.2 domain independent expert system shell. It integrated the ESs shell using blackboard architecture elements & the NN simulator. Knowledge representation can be done as declarative expressed rules, facts and distributing knowledge in the NN

In paper 'Design of a hybrid system for the diabetes and heart diseases', by Humar Kahramanli, Novruz Allahverdi, [14] designed a hybrid system which classifies the diabetes and heart disease using neuro-fuzzy technique. For diabetes, Pima Indian pregnant women diabetes dataset of 768 samples with 8 attributes used. The system uses ANN with six inputs and FNN with two inputs. The classification accuracy is 87.2% sensitivity is 80.3% and specificity is 87.3%. For Heart disease diagnosis it uses both fuzzy and crisp data with hybrid NN which includes ANN and FNN, with backpropagation algorithm.

Some expert systems use open source platform for implementation. The ES implemented in [21] is open source, web-based system with Google App Engine and cloud computing technique to manage the diabetes and give the advice/treatment. Already diagnosed patients of diabetes can make use of this system. The inputs for this system are diabetes type and 3 blood sugar tests. It gives the appropriate treatment based on the diabetes type such as diet plan, insulin intake, planned physical activity, oral medicines etc. The system is already tested with different type of diabetes and by the help of 2 physicians. It also provides the facility to store the patient's record if required for future use.

The multiagent system approach used by Baran Hashemi, Hossein Javidnia,[22] for recommendations in hypo or hyperglycemic conditions. The ES gives appropriate recommendations, on the basis of signs & symptoms and patients blood glucose level. Various agents in this system are blood glucose tests in different situations like fasting, postprandial, bedtime, random etc. It is useful for both experts and diabetic patients. It also recommends the nutritious food in terms of calorie, proteins and carbohydrates based on patient's weight, height, age, physical activity, BMI.

The Brain Derived Neurotropic Factor (BDNF) levels and Blood Fasting Glucose (FBG) are used for diagnosis. [18] Clinical parameters such as age, gender, BMI, HDL, LDL, FBG also used, the range of which is different for male and female patients. It is a rule-based expert system which uses knowledge base, inference engine to infer conclusions, from the knowledge base. The ES classifies the diabetes conditions separately for male and female as prediabetic condition, diabetic condition and diabetic free healthy condition. A data of 260 patients (128-Male and 132-Female) used for testing.

Automatic diagnosis of diabetes can be done by analysing signs and symptoms. In addition, blood test for sugar level is important factor for confirming the diabetes. Generally, fasting glucose and 2 hours post-meal glucose level tests are

used. Symptoms will helpful in early treatment. Various agents are used to identify each signs and symptoms. Diagnosis can be made by interoperability of agents and it also suggests the treatment. [23]

## VI. CONCLUSION

There is a need for research in diagnosis of diabetes which is helpful for medical practitioners and patients. This paper discussed expert systems for both diagnosing and treatment of diabetes. It clearly shows that, there are several expert systems developed which are used either for diagnosis or treatment of diabetes. Majority of expert systems uses Pima Indian pregnant women dataset for diagnosis purpose. However, some systems used the patient's data from hospital. The methodologies used for diagnosis/classification of diabetes are soft computing techniques like neural network, fuzzy systems. The hybrid approach which is the fusion of neural network and fuzzy system is also useful means for diagnosis process.

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