An Expert System for Diabetes Diagnosis

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Abstract: During the recent decades, using expert systems has been developed in a vast level in all sectors of human being life, in particular in the field of medicine. The main objective of this research was to design an expert system for diagnosis all types of diabetes. After data acquisition and designing a rule-based expert system, this system has been coded with VP_Expert Shell and tested in Shahid Hasheminezhad Teaching Hospital affiliated to Tehran University of Medical Sciences and final expert system has been presented. Findings of this research showed that in many parts of medical science and health care the expert systems have been used effectively. The acquisitive knowledge was represented in the diagrams, charts and tables. The related source code using of the expert system was given and after testing the system, finally its validation has been done. It has been concluded here the expert system can be used effectively in all areas of medical sciences. In particular, in terms of vast number diabetics throughout the world, the expert system can be highly helpful for the patients. These patients in many cases are not aware of their disease and how to control it. In addition, some of these patients do not access to the physicians during necessary times. Therefore, such a system can provide necessary information about the indications and diagnosis. Since this expert system gathers its knowledge from several medical specialists, the system has a broader scope and can be more helpful to the patients -- in comparison to just one physician.

Keywords: Expert System, VP_Expert, Diabetes Diagnosis, Hasheminezhad Teaching Hospitals

1. Introduction

During the recent decades, expert systems have been used in some fields including medicine in the developed countries. Yet, in some of the medical areas, major activity for using of expert systems in diagnosis and treatment of related disease, teaching to medical students, advising to patients have not been done. This problem causes spending too much time and money, lack of timely access to physicians, and finally jeopardizing human lives.

In fact, the medical field was one of the first testing grounds for Expert System (ES) technology. MYCIN, NURSExpert, CENTAUR, DIAGNOSER, MEDI and GUIDON, MEDICS, and DiagFH are few of the first and successful medical Expert System.

An Expert System is a computer program that attempts to imitate the reasoning process and knowledge of experts in solving specific types of problems (Garcia et al., 2001).Garcia indicates that Jackson believes that an Expert System is a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice.

Today, based on the statistics of International Federation of Diabetes, there are 230 millions of diabetics through the world, at present time which 80 percent of them are living in the developing countries. Up to 2025, number of diabetics will reach to 380 million (Ghaffari, 2009). Rajab, director of Iran Diabetes Association indicates that yearly about one billion US dollars is expended in the country because of non-controlling of diabetes (Rajab, 2010). Over 4 millions of Iranians are diabetes in the country and about such a rate are facing to the danger of diabetes (Khosrownia 2010). Iran is located in a district which diabetes epidemic is more than universal statics (Ghaffari, 2009). According to Rajab indication, 1/5 of Iranians are diabetics or facing with diabetes danger. Treatment cost of diabetes type II and its side effect is 24 times of its treatment cost without side effect; While 99% of diabetics have not benefit from a proper control (Rajab, 2010). Omidi, managing director of the Country Charitable Support of Diabetic Association, has announced that based upon the existing statics, in average 10% of Iran inhabitants are diabetics—which means 7 million people. He adds that "today, the most epidemic factor of disabilities in the country such as blindness, amputation, kidney degeneration and sex disabilities are side effects of diabetes (Omidi, 2010).Lee, et al. have presented a system consists of a network system to collect data and a sensor module which measures pulse, blood pressure and so on. They have proposed an expert system using back-propagation to support the diagnosis of citizens in U-health system (Lee et al. 2012). Chen, et al. have represented a three- stage expert system based on support vector machines for thyroid disease diagnosis. They have tried to focus on feature selection, the first stage aims at construction diverse feature subsets with different discriminative capability. In the second stage, the proposed system was used for training an optimal predictor model. Finally, the obtained optimal SVM model proceeded to perform the thyroid disease diagnosis tasks using the most discriminative feature subset and the optimal parameters. They believed that the proposed FS-PSO-SVM expert system might serve as a new candidate of powerful tools for diagnosing thyroid disease with excellent performance (Chen et al, 2011).

Keles, Keles and Yavuz have developed an expert system so called as an Ex-DBC (Expert System for Diagnosis of Breast Cancer). They indicated that the fuzzy rules which will be used in inference engine of Ex-DBC system were found by using neuro- fuzzy method. Ex-DBC can be used as a strong diagnostic tool with 97% specificity, 76% sensitivity, 96% positive and 81% negative predictive values for diagnosing of breast cancer. In addition, they asserted that by means of that system can be prevented unnecessary biopsy (Keles, Keles and Ugur, 2011). Adeli and Neshat have tried to design a system with 13 input fields and one output field. Input fields were chest pain type, blood pressure, cholesterol, resting blood sugar, maximum heart rate, resting electrocardiography (ECG), exercise, old peak, thallium scan, sex and age. The results obtained from their designed system were compared with the data in upon database and observed results of designed system were correct in 94%. The system coded with MATLAB software (Adeli, Neshat, 2010)

Zarandi, et al. have designed a fuzzy rule-based expert system for diagnosing asthma. They assert that a knowledge representation of the system was provided from a high level, base on patient perception, and organized into two different structures called Type A and Type B. Type A is composed of 6 modules, including symptoms, allergic rhinitis, genetic factors, symptom hyper-responsiveness, medical factors and environmental factors. Type B was composed of 8 modules, including symptoms, allergic rhinitis, genetic factors, response to tests, PEF tests and exhaled nitric oxide. They concluded that the final results of every system are de-fuzzyfied in order to provide the assessment of the possibility of asthma for the patient (Fazel-Zarandi et al. 2010). Singh, et al. have presented an expert system design and analysis for breast cancer diagnosis. The algorithm for rule-based reasoning was addressed which was developed for mammographic findings to provide support for the clinical decision to perform biopsy of the breast. The designed system was evaluated using a round-robin sampling scheme and performed with an area under the receiver operating characteristic curve of 0.83, comparable with the performance of a neural network model (Singh, et al. 2010).

Zolnoori, Fazel-Zarandi and Moin have developed a fuzzy rule-base expert system for evaluation possibility of fatal asthma. Fuzzy-rules, modular representation of variables in regard to patients' perception of the disease, and minimizing the need for laboratory data were the most important features of the system main variables of viral infections. Evaluating the performance of the system at asthma, allergy, immunology research center of Imam Khomeini Hospital reinforced the good efficiency of that fuzzy expert system for prediction of possibility of fatal asthma (Zolnoori, et al. 2010). Akter, Sharif-Uddin, and Aminul-Haque have provided a knowledge-based system for diagnosis and management of diabetes mellitus. They believed that preventive care helps in controlling the severity of chronic disease of diabetes. In addition, preventive measures require proper educational awareness and routine health checks. The main purpose of this research was developing a low-cost automated knowledge-based system with easy computer interface. This system performs the diagnostic tasks using rules achieved from medical doctors on the basis of patients' data (Akter, Shorif Uddin, Haque, 2009).

Karabatak and Cevdat Ince have peresented an expert system for detection of breast cancer based on association rules and neural network. They have developed an automatic diagnosis system for detecting breast cancer based on association rules (AR) and neural network (NN). The proposed AR+NN system performance was compared with NN model. The dimensions of input feature space were reduced from nine to four by using AR. Validation of this system was applied at Wisconsin Breast Cancer Database and the correct classification rate of the proposed system showed 95.6%. They concluded that AR+NN model can be used to obtain fast automatic diagnostic systems for other disease (Karabatak, Cevdet, 2009).

2. Diabetes

Diabetes is a defect in the body's ability to convert glucose (sugar) to energy. Glucose is the main source of fuel for our body. Diabetes develops when the pancreas fails to produce sufficient quantities of insulin – Type 1 diabetes or the insulin produced is defective and cannot move glucose into the cells – Type 2 diabetes. Either insulin is not produced in sufficient quantities or the insulin produced is defective and cannot move the glucose into the cells Diabetes Research Wellness Foundation, 2011).

There are three types of diabetes. Type 1 diabetes, Type 2 diabetes, and Gestational diabetes. Each one is briefly described.

(1) **Type 1 Diabetes**

It was previously called insulin-dependent diabetes mellitus (IDDM). Type 1 diabetes may account for 5% to 10% of all diagnosed cases of diabetes. Risk factors are less well defined for type 1 diabetes than for type 2 diabetes. Genetic and environmental factors are involved in the development of this type of diabetes.

(2) **Type 2 Diabetes**

It was previously called non-insulin-dependent diabetes mellitus (NIDDM) or adult-onset diabetes. Type 2 diabetes may account for about 90% to 95% of all diagnosed cases of diabetes. Risk factors for type 2 diabetes includes older age, obesity, family history of diabetes, prior history of gestational diabetes, impaired glucose tolerance, physical inactivity, and race/ethnicity.

(3) **Gestational Diabetes**

It develops in 2% to 5% of all pregnancies but usually disappears when a pregnancy is over. Pregnant women have enough insulin, but the effect of insulin is partially blocked by variety of other hormones produced in the placenta. This condition is called insulin resistance (Garcia et al., 2001).

3. Expert Systems

Expert systems are computer programs that solve problems in a non- procedural manner using knowledge from human experts to simulate human reasoning. They are also called knowledge-based systems or inference-based programs. The intelligent activity they are emulating is problem solving and they use knowledge for their processing rather that just information (De Tore, 1989). According to Olson and Courtney (1992) expert systems are computer programs within a specific domain, involving a certain amount of AI to emulate human thinking in order to arrive at the same conclusions as a human expert would. Expert systems can deal with incomplete and uncertain data in reaching conclusions and incorporates an explanation for its reasoning process. Turban et al. (2001) define expert system as computer advisory programs that attempt to imitate the reasoning processes of experts in solving difficult problems. Expert system has the ability to perform at the level of an expert, representing domain specific knowledge, in the way an expert thinks (De Kock, 2003).

Most expert systems have similar basic components. They include a knowledge base, an inference engine and a user interface. The knowledge base is the programmed knowledge of the expert, both the 'book knowledge" and the practical knowledge or heuristics. This holds all of the pertinent facts and relationships about the subject as well as the rules of thumb to effectively search through those facts to solve problems. The inference engine is the real "know how" of an expert system which can apply the knowledge from the knowledge base to solve the problem. It is the part of the program which is responsible for how to get from the initial information to the final solution (De Tore, 1989).

4. Expert Systems in the Field of Medicine

Varieties of expert systems have been developed in the area of medical sciences. Following major expert systems in the field of medicine have been expressed:

- PUFF: Pulmonary disease diagnosis
- VM: Monitoring of patients need to intensive care
- ABEL: Diagnosis of acidic materials and electrolytes
- AI/COAG: Blood disease diagnosis
- AI/RHEUM: Rheumatic disease diagnosis
- CADUCEUS: Internal medicine disease diagnosis
- ANNA: Monitoring and treatment analysis
- BLUEBOX: Depression diagnosis and treatment
- MYCIN: Microbial disease diagnosis and treatment
- ONCOCIN: Treatment and management of patients chemotherapy
- ATTENDING: Anesthesia management education
- GUIDON: Microbial disease education (Ghazanfari, Kazemi, 2010).

5. The Expert System Development

We have tried to develop an expert system for diabetes which summarized in 10 phases, as follows:

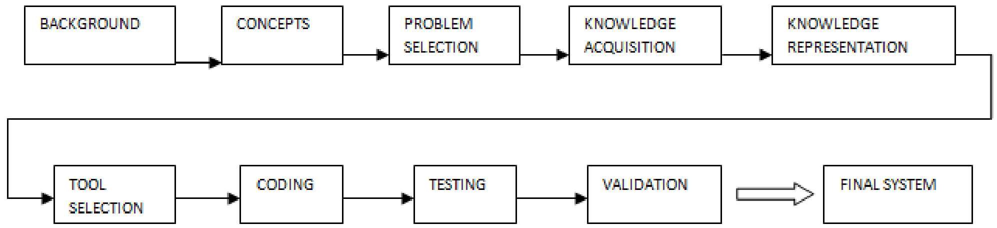

Figure 1: Stages of Designing and Implementation of the Diabetes Expert System

5.1 Knowledge Acquisition

The knowledge acquisition method in this research was direct interview. The knowledge acquisition for this study was consisted of:

a) Intensive study of scientific materials including medical textbooks, scientific articles, Ph.D. dissertations and master theses— to be familiar with the study area, vast and scientifically.
b) Interviews with several specialists in internal medicine and diabetes, as major referees, scientifically as well as practically.
c) Interviews with the nurses of diabetes section of Shahid Hasheminezhad and Modares Teaching Hospitals respectively affiliated to Tehran University of Medical Sciences and Beheshti University of Medical Sciences.
d) Developing primary questions, making required corrections in each phase and subsequently my expert system design based on the former stages.

5.2 Knowledge Representation

As the designed system is a rule-based expert system, for knowledge representing some rules have been used. Structure of these rules is IF ⟶ THEN. IF is demonstrating the situation and THEN shows the suggestion. For transforming experts' knowledge to these rules, there are three stages that should be handled including: Block Diagram**,** Mockler Charts**,** Decision Tables.

For diagnosing diabetes, in the first stage the knowledge has been represented in a block diagram as below:

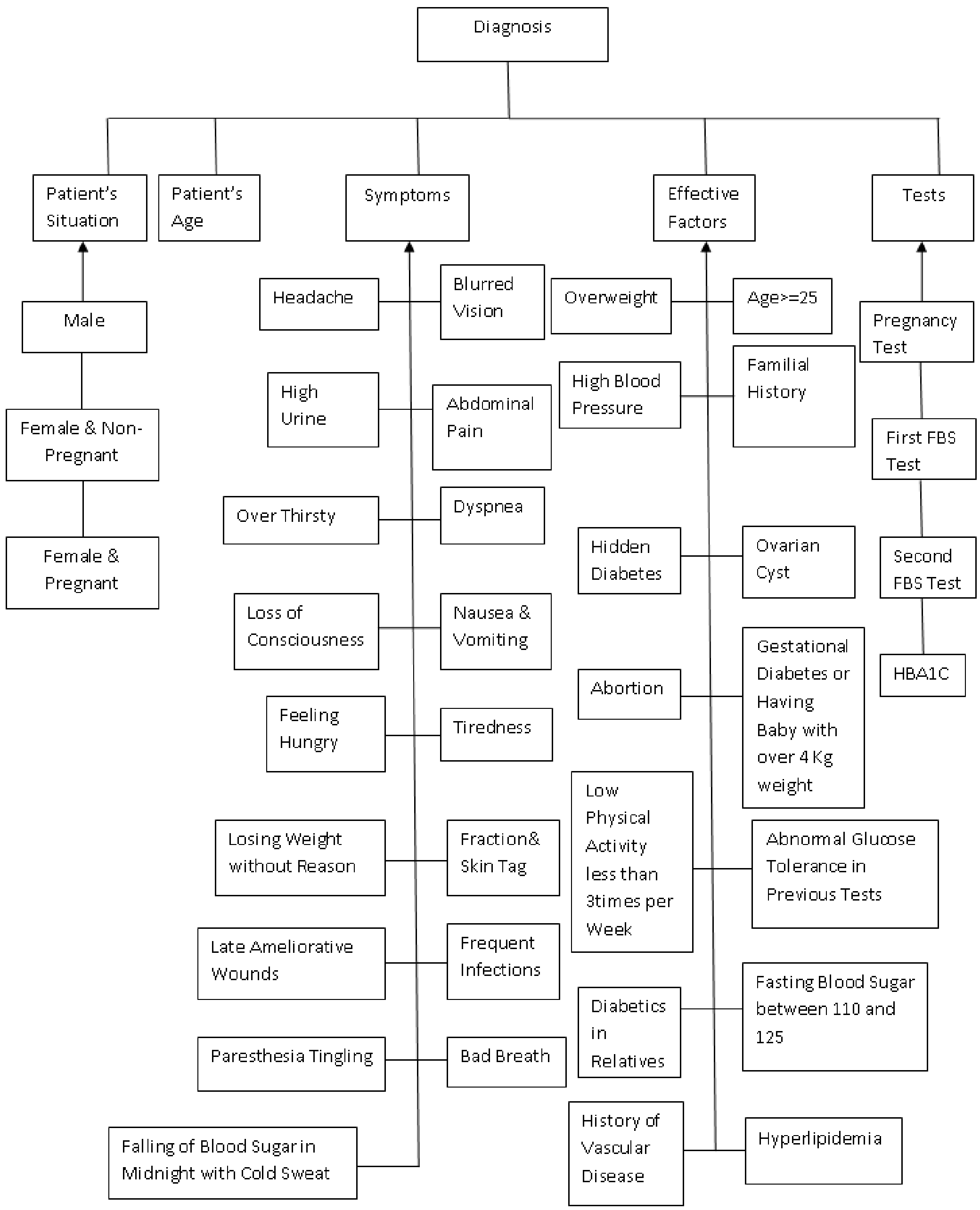

Figure 2: The Block Diagram of Diagnosis

The diagnosis has 6 states: 1) Healthy, 2) At Risk, 3) Diabetes Type I, 4) Diabetes Type II, 5) Gestational Diabetes and 6) Consultation with Physician. The diagnosing part is composed of 5 attributes which different combinations of these attributes would tend to various diagnoses.

The next stage is designing the related Mockler Charts based on the former block diagram, in which the questions that user must answer and choices that he has to decide would be demonstrated. This system needed 4 Mockler Charts consists of: Diagnosis, Symptoms, Effective Factors and Tests.

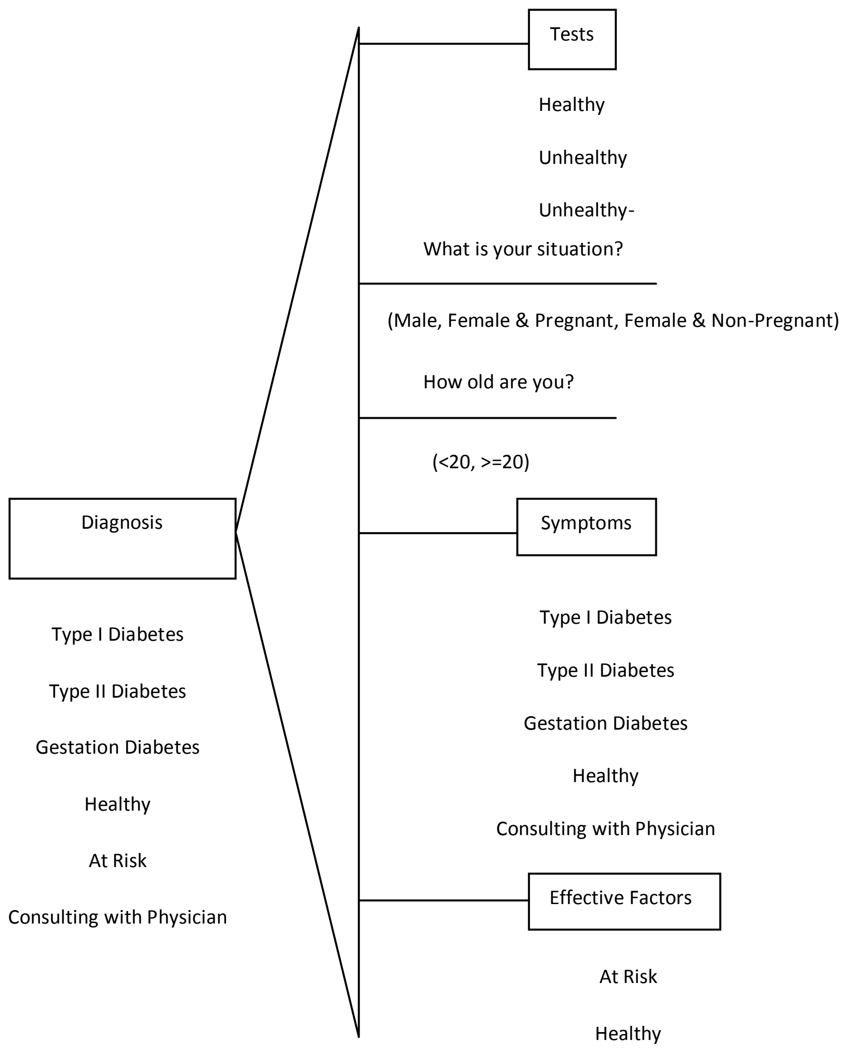

Figure 3: The Mockler Chart of Diagnosis Expert System

This Mockler Chart of diagnosis has been drawn to show the relation of tests, patient's situation, patient's age, symptoms and effective factors.

In the Mockler Chart of symptoms, the questions and choices related to determining of the patient's symptoms which concluded diabetes or healthy of the patient. In the Effective Factors Mockler Chart the questions and choices that determine whether the patient is at risk or healthy status has been demonstrated. The last Mockler Chart is related to the diagnosis tests of the patients to show and determine the situation of the patient.

After drawing the Mockler Charts, it is necessary to provide the related decision tables based on the pertinent Mockler Chart.

Table 1: The Decision Table of Symptoms

Diagnosis / Symptoms	Healthy	Diabetes
Headache	No	Yes
Blurry Vision	No	Yes
Excessive Urination	No	Yes
Bellyache	No	Yes
Over Thirsty	No	Yes
Feeling Pursiness	No	Yes
Loss of Consciousness	No	Yes
Nausea & Vomiting	No	Yes
Feeling Hungry	No	Yes
Tiredness	No	Yes
Losing Weight without Reason	No	Yes
Fraction& Skin Tag	No	Yes
Late Ameliorative Wounds	No	Yes
Frequent Infections	No	Yes
Loss of Sensation in Hands and Feet	No	Yes
Bad Breath	No	Yes
Falling of Blood Sugar in Midnight with Cold Sweat	No	Yes

In the symptoms decision table, based upon the different symptoms the situation of the patient would be determined. Each row of this table is a rule of symptoms and in all 17 rules for symptoms is existed.

Table 2: The Decision Table of Effective Factors

Effective Factors \ Diagnosis	Healthy	At Risk
Overweight	No	Yes
Age	<25	>=25
Blood Pressure	<140/90 Mm Hg	>=140/90 Mm Hg
Diabetic Parents or siblings	No	Yes
Hidden Diabetes	No	Yes
Rate of Triglycerides	<200	>=200
Abortion	No	Yes
Gestational Diabetes or Having Baby with over 4 Kg weight	No	Yes
Low Physical Activity (less than 3 times per Week)	No	Yes
Disorder in Glucose Tolerance in Previous Tests	No	Yes
Diabetics in Relatives	No	Yes
Rate of Fasting Blood Sugar between 110 and 125	No	Yes
History of Vascular Disease	No	Yes
Ovary Syndrome or Numerous Cysts	No	Yes

In table 2 related to the effective factors, the patient's conditions of healthy or at risk, based on 14 rules have been shown.

In table 3, the necessary tests reports including: Pregnancy, First Fasting Blood Sugar (FBS1), Second Fasting Blood Sugar (FBS2), HBA1C and finally the decision about the condition of the patient have been demonstrated.

Table 3: The Decision Table of Tests

Pregnancy	FBS 1	FBS 2	HBA1C	Tests
---	<126	>=126	>=6%	Unhealthy
---	<126	<126	< 6%	Healthy
Female & Non-Pregnant	>=126	>=126	---	Unhealthy
Female & Pregnant	>=126	>=126	>=6%	Unhealthy
Female & Pregnant	>=126	>=126	<6%	Unhealthy-Gestational
None	>=126	>=126	---	Unhealthy
None	<126	>=126	<6%	Healthy
None	>=126	<126	<6%	Healthy
---	>=126	<126	>=6%	Unhealthy
---	<126	<126	>=6%	More Consideration
Female & Non-	<126	>=126	<6%	Healthy

Pregnant				
Female & Pregnant	<126	>=126	<6%	More Consideration
Female & Non-Pregnant	>=126	<126	<6%	Healthy
Female & Pregnant	>=126	<126	<6%	More Consideration

The final table is decision table of diagnosis which shows various combinations of patient's situation, patient's age, symptoms, effective factors and tests and by analyzing them provides the final decision of diagnosis. It is clear each row of this table shows a rule of diagnosis decision.

Table 4: The Decision Table of Diagnosis

Tests	Patient's Situation	Patient's age	Symptoms	Effective Factors	Diagnosis
Healthy	---	---	Healthy	Healthy	Healthy
Healthy	---	---	Healthy	At Risk	At Risk
Healthy	---	---	Diabetes	At Risk	At Risk
Healthy	---	---	Diabetes	Healthy	More Consideration
Unhealthy	Male	<20	Diabetes	---	Diabetes Type I
Unhealthy	Male	>=20	Diabetes	---	Diabetes Type II
Unhealthy	Female & Non-Pregnant	<20	Diabetes	---	Diabetes Type I
Unhealthy-Gestational	Female & Pregnant	---	Diabetes	---	Gestational Diabetes
Unhealthy	Female & Pregnant	>=20	Diabetes	---	Diabetes Type II
Unhealthy	Female & Pregnant	<20	---	---	More Consideration
Unhealthy	---	---	Healthy	---	More Consideration
Unhealthy	Female & Non-Pregnant	>=20	Diabetes	---	Diabetes Type II
Unhealthy-Gestational	Female & Pregnant	---	Healthy	---	More Consideration
More Consideration	---	---	---	---	More Consideration

5.3 Coding

VP-Expert (Khashavi-Najafabadi, Bayat, 2010), (VP_Expert Primer) has been chosen for coding the expert system for diabetes. VP-Expert is a specific tool for developing expert systems, therefore only expert systems designers are familiar with this tool. Like any shell, it contains everything needed for running the expert system (except for **knowledge base** of rules for the particular domain). This includes:

- An **inference engine** for consulting the knowledge base in order to answer queries.
- An **editor** for creating/writing the rules of the knowledge base. (WordPad can be used as an editor for VP-Expert Shell).
- A **user interface** capable of handling queries, asking the user questions, and presenting traces and explanations where needed. It also has limited graphical capabilities.

```
Rule assessment_7
if test=unhealthy and
your_situation=female_and_non_pregnant and
your_age= yes and
symptoms=diabetes
then assessment= diabetes type I ;
```

Figure 4: A sample of the expert system rule

5.4 Testing and Validation

In the trend of developing the system, all rules, paths and relationships between attributes have been tested and the necessary changes have been done. The designed system has been evaluated by the internists and diabetes specialists of Shahid Hasheminezhad Teaching Hospital. After validation and approval the system, the final designed system has been provided.

6. A Sample of Running the Expert System

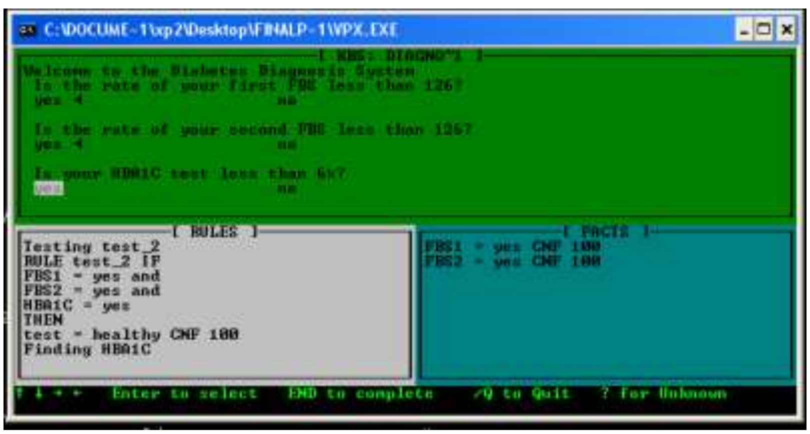

Figure 5: Some system questions from user about rate of the blood sugar

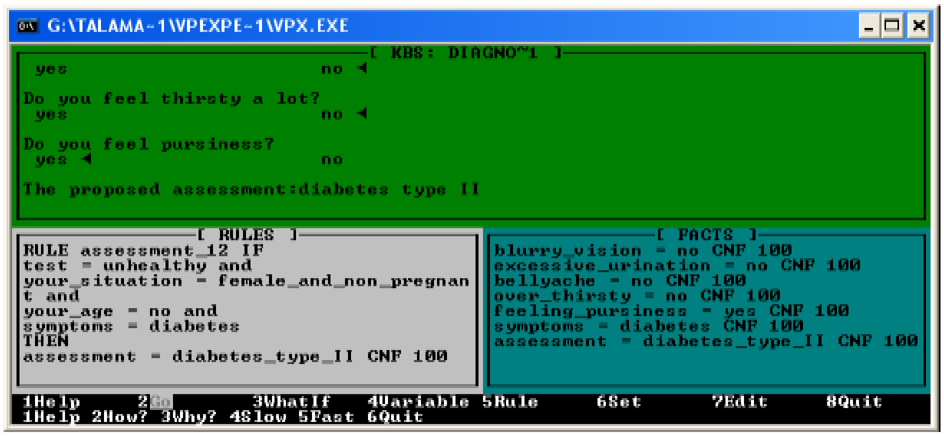

Figure 6: The System diagnosis Sample

As shown in figure6, after asking related questions, the diagnosis system has declared the final decision.

7. Conclusion

As conclusion, it should be mentioned the expert system can be used effectively in all areas of medical sciences. In particular, in terms of vast number of diabetics throughout the world, the expert system can be highly helpful for the patients. These patients in many cases are not aware of their disease and how to control it. In addition, some of these patients do not access to the physicians during necessary times. Therefore, such a system can provide necessary information about the indications, diagnosis and primary treatment advices to the diabetics. Since this expert system gathers its knowledge from several medical specialists, the system has a broader scope and can be more helpful to the patients -- in comparison to just one physician.

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