Literature Synthesis:
Expert System for Diabetes Advice

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Abstract

This research paper is a literate review of various experts systems and how they are applied in a medical context, with the ultimate aim of this project being to develop an interactive, web-based expert system that offers advice on Diabetes to users, irrespective of literacy levels. Diabetes is a chronic disease that affects millions of people worldwide and statistics from the International Diabetes Foundation state that currently 50% of diabetics are unknowingly living with the disease .With no known cure the best approach to ensuring a prolonged life as a diabetic is taking the right medication and living a healthy lifestyle. Unfortunately low literacy levels, lack of information and limited access to professional medical experts further compounds the problem of unawareness. However, expert systems can successfully be used as medical diagnostic tools as well as act in an advisory capacity to alleviate this problem.

Introduction

Expert systems are a subfield of Artificial Intelligence (A.I) that aim to model the behavior of a human expert [1]. They are computer software systems that use artificial intelligence to solve a problem or provide advice for specific situations known as problem domains, which would usually require the elicitation of professional human expertise. These systems are based on the transfer of expert human knowledge from one or more experts in a field into a computer system through the process of knowledge engineering; this allows the system to be utilized in an expert-like advisory capacity [2].

Expert systems are used in a variety of different situations and their applications can range from different fields such as agriculture, finance, education, medicine, military services, process control, space technology and engineering [3]. These specialized services can make an unprecedented impact in developing countries where there is a clear need for an improvement in facilities like healthcare, training and education. The ultimate goal of this honours' project is to develop a user friendly, web-based, medical expert system with the ability to provide comprehensive medical advice and even possibly a diagnosis on diabetes to normal everyday users, catering for different levels of literacy.

Diabetes is a very common chronic disease that can quickly lead to death if it is not detected and treated in time. It arises when the pancreas does not produce enough insulin, or when the body fails to make proper use of the insulin that it does produce. If this condition is not dealt with correctly it will inevitably cause long term damage to the body and the eventual failure of important organs.

Unfortunately this disease is not curable but it can be controlled and managed with the administration of the right medication and the appropriate corresponding lifestyle changes, namely consistent fitness and a controlled diet.

Early diabetes diagnosis and awareness can honestly be the difference between life and death for a diabetic.

Taking all this into consideration, it is evident that the use of a specialized diabetes medical expert system could be utilized to educate people about diabetes; the symptoms that come with it and the possible treatments of diabetes in a timely and efficient manner, all in the absence of a qualified medical doctor.

The outline of the rest of this paper involves a more in-depth discussion of diabetes, previous medical expert systems and the usability of these systems.

Diabetes

"Diabetes mellitus" also known simply as Diabetes, describes a group of metabolic diseases in which a person has a high count of blood glucose (sugar). This occurs mainly because of the following two reasons:

1. The body does not produce a sufficient amount of insulin.
2. The cells in the body do not react appropriately to the insulin.

Insulin is a hormone produced and secreted naturally within the pancreas that is used to control the amount of glucose in the blood. The normal production of insulin allows muscles and other tissue within the body to take glucose from the blood and convert it into energy. Administering insulin to a diabetic does not cure the Diabetes but it does make living with the disease a lot more manageable in the long term. Before its discovery in the early in the 20th century, Diabetes was a greatly feared disease with diabetics quickly succumbing to their death without the hope of prolonged survival.

The categories of diabetes are as follows:

- **Type1 Diabetes**

  Often referred to as insulin-dependent or juvenile diabetes, it is when the body does not produce insulin. It is mostly seen in children and young adults [1]. Type1 Diabetes accounts for about 5% to 10% of all diagnosed cases of diabetes.

- **Type2 Diabetes**

  Either the body does not produce enough insulin for proper everyday functioning or the cells do not react properly to the insulin. Type2 diabetes is the most common variety of diabetes in the world as it accounts for about 90%-95% of all types of diabetes [4].

- **Gestational diabetes**

  This occurs in about 2-5 % of all pregnancies but it usually disappears when the pregnancy is over. Some women have high glucose levels in their blood during pregnancy and their bodies are not able to produce enough insulin to properly deal with it. It shows many similarities to Type 2 diabetes [1]

According to the IDF (International Diabetes Foundation) 50% of the current diabetic population are unaware that they have the disease, thus they do not know how to manage their lives properly as they unknowingly live with this fatal disease.

This high percentage of undiagnosed diabetics is the direct result of a lack of awareness and education on diabetes coupled with the likelihood that these people are not able to access medical doctors (especially in developing countries).

It is believed that preventive measures assist greatly in controlling the severity of Diabetes, but these measures require proper educational awareness and frequent health checks [4]. The use of a medical expert system aimed at offering comprehensive diabetes-related advice and diagnosis could play a huge role in the areas where this is a problem.

Medical Expert Systems

Eliciting services from qualified medical doctors in certain areas can be very difficult, both on account of the high cost involved as well as the scarcity of these professionals .Studies done by the World Health Organization show that South Africa had 7.7 Doctors to every 10,000 people (2012). This is a relatively low ratio when compared to a different study done by WHO with results that state that European countries like Greece have up to 62 Doctors per 10,000 people (2012). The low availability of Doctors coupled with the low literacy levels in rural Sub Saharan Africa [5] is further evidence of the potential impact that expert systems used for medical applications can make in such areas.

Medical Expert systems have the ability to offer comprehensive medical advice, education and training; with the ability to successfully diagnose (to a certain degree of accuracy) certain conditions and diseases in the absence of a professional doctor. Along with this, such systems can also be utilized to further assist doctors to make informed decisions about their patients with the use of highly computational and mathematically oriented tools. If such systems are developed correctly and deployed appropriately, the healthcare system will be impacted greatly, as both doctors and patients are directly affected.

In the last few decades various medical expert systems have been developed for the following purposes:

- To diagnose meningitis and bacterial infections [6].
- To give nutritional diagnosis [7].
- To assist with the diagnosis of brain tumours [2].
- To efficiently identify and differentiate between benign and malignant breast cancer [8].

*This is by no means an exhaustive list of all the previously developed medical expert systems, but serves to show the variety that exists.

Previous expert systems

DENDRAL is a chemical expert system regarded as the first ever knowledge-driven, rule-based program to apply to a real-world problem [9]. This system was the first to modularize the knowledge base from the code that uses it and its success is greatly attributed to the extensive amount of chemical knowledge that it made use of [9]. Mainly designed for use by chemists, the aim of DENDRAL was to assist organic chemists in identifying unknown organic molecules. It did this by analyzing the mass spectra of an unknown compound and utilizing its chemistry knowledge to come to a conclusion. As the weight of the unknown compounds increased, the molecules become more intricate and the range of possible solutions escalates. Thus, the use of DENDRAL was essential to simplify this process. DENDRAL was written in the LISP programming language.

MYCIN was developed at Stanford University in the mid 1970’s shortly after DENDRAL. It was designed to assist doctors in the diagnosis and treatment of meningitis and bacteremia infections [6] Positive in-laboratory identification of these fatal and infectious blood diseases could take up to two full days. The severity of such a situation meant that in most cases treatment needs to be administered in the absence of complete laboratory results, as there was a need to act quickly in order to identify the exact cause and prescribe the right medication in a timely manner. Thus the role of MYCIN was to effectively take the place of a consulting physician that specialized in bacteremia and meningitis. To achieve this, MYCIN would engage in an extensive dialogue with the doctor, asking numerous questions consecutively until eventually providing a diagnosis and a drug therapy recommendation. MYCIN was also written in the LISP programming language.

DENDRAL was used in practice, MYCIN was strictly for research purposes [6] yet both systems were regarded as highly successful. Their success can be attributed to a number of things, in particular their large and comprehensive knowledge base. This is done through a process called knowledge engineering; both DENDRAL and MYCIN had an extensive rule base that allows them to reach certain conclusions. Flexibility of these expert systems also plays a vital role; MYCIN was able to come to conclusions with incomplete information (“UNKNOWN” is a valid answer), much like a human expert would. Also allowing the user to answer questions with certain levels of uncertainty (I.e. a “YES” or “NO” answer could be followed with a decimal value between -1 and 1 to cater for certainty). Expert systems that encounter and manage the process of dealing with uncertainty in the knowledge base are known as fuzzy expert systems, which deal with data that does not always conform to typical Boolean values by the use of fuzzy logic [14].

The tractability of these systems allowed for rules to be edited, added or removed [7] at any time ,thus allowing the systems to be continuously modified and kept up to date- a feature that is extremely important for an expert system associated with the ever growing scientific and medical fields. DENDRAL and MYCIN were both written in the LISP programming language which at the time of development was considered “the language of AI” [9].

Expert systems with applications in diabetes

According to [10] the Diabetes Mellitus problem can be categorized into four distinct areas:

1. The diagnosis of Diabetes Mellitus.
2. The Treatment of Diagnosis Diabetes Mellitus.
3. The diagnosis of Diabetic complications.
4. The treatment of diabetic complications.

Various expert systems have been developed that target each of these four areas.

DIABETES is a rule-based expert system prototype that specializes in insulin management for diabetics [10]. It takes the following values as input from the patient:

1. The regimen type that the patient is currently on.
2. The Insulin dosage of the patient.
3. Blood glucose levels at different times of the day.

4. The symptoms of glycaemia if blood glucose levels are unknown.

*Glycaemia is the presence of glucose in the blood

After receiving the above as input; DIABETES will offer an adjusted insulin regimen if necessary, comments on the patients glycemic control and it also suggests follow up therapy [10]. During performance testing, DIABETES was compared head to head with medical experts on 600 patients that were each on one of the four regimes supported by DIABETES. The results stated that the system counseled in a way very similar to that of the medical experts, with a 65% agreement (some cases with minor deviations) on patient cases [10].

DIABETES had limitations with regards to input as it did not take factors such as weight, physical activity and nutrition into consideration. Such factors could be utilized in making more precise final recommendations, but would require an even more complex rule-base. Furthermore, DIABETES was not able to introduce other insulin regimes to the patient, a task that a human expert can easily perform.

The success of this and similar expert systems implemented in a real world context would result in large cost saving for patients directly from reduced consultation hours with professional human experts.

ESDD, an Expert System for Diabetes Diagnosis is a rule based medical expert system for the diagnosis of diabetes [4]. This system has three main menu options:

1. Diagnosis.
2. Complications.
3. Diabetes trainer.

It is not able to identify the type of diabetes (Type1, Type2 or gestational Diabetes) but it can identify the level of diabetes risk in the patient. ESDD is comprised of an extensive list of symptoms stored in the fact base, different rules exist for different symptoms, there is a rule base of 41 distinct rules. ESDD makes use of a text-oriented menu-based user interface to interact with the user, communicating in simple English. Its simplicity and ease of use means that no special training is required to use ESDD, thus enabling a lay person to utilize its services. ESDD has a trainer option that can be used to provide diabetes awareness amongst the public, also during the diagnosis process the system is able to give comprehensive explanations about the causes of the disease, a lengthy task that a professional medical expert may not be able to accomplish because of time constraints. This expert system was developed in 2010 and was written in the CLIPS programming language.

MAS, Medical Advisor System is a knowledge-based expert system prototype completed as part of a UCT (University of Cape Town) honours' project in 2012 [11]. This system offers information about diabetes and advice on diabetes management. MAS has two main menu options

1. Medical Advisor System.
2. Diabetes Information.

It does not diagnose Diabetes and it does not offer treatment either, rather it serves as an informative tool for diabetes management and awareness. Patients who are unaware of their Diabetes status

Name	Year Developed	Programming Language	Developmental state	User Interface	Targeted Users-base
DENDRAL	1960’s	LISP	In use (at the time)	Text-based	Chemists
MYCIN	1970’s	LISP	Research purposes	Text-based	Physicians
DIABETES	Prior to 1996	N/A	Prototype	Text-based	Diabetics
ESDD	2010	CLIPS	Prototype	Text-based	Open to all
MAS	2012	JESS	Prototype	Text-based	Open to all

Table1: Summary of the expert systems mentioned.

are referred to the clinic to get professional advice if they seek a medical diagnosis.

Similarly to ESDD, MAS makes use of a menu-based text oriented user interface with a simplified use of the English language. MAS was developed with the aim of assisting users of different literacy levels, targeting users based in rural South Africa. MAS was written in the JESS (Java Expert System Shell) programming language.

The above table summarizes the expert systems mentioned. LISP was the programming language of choice, with other languages like Prolog, VP-Expert [12] and Delphi [1] being used in previous expert systems. Recent expert systems have made use of CLIPS and JESS, which are very similar to each other, with JESS being a superset of CLIPSE.

The reason that expert systems are not immediately deployed and freely available to the public, like the likes of ESDD and MAS is because there are a lot of legal issues [13] and health risks involved, for instance if users are given the wrong diagnosis and advised to follow incorrect treatment. Worse yet the case of a false positive where a diabetic could incorrectly be deemed healthy, the repercussions are enormous. As successful as MYCIN was, it still misdiagnosed about 35% of its cases [13]. This is why extensive testing must be done to prove and ensure the range of accuracy of such systems.

However as stated by [13] “Validation does not carry with it a seal of perfection, as it can lessen but not eliminate mistakes”.

User interfaces and usability is also a major concern, as one of the reasons that MYCIN was not used in practice was because it could take up to 30 minutes of a doctor’s time just to input patient data into the system. This is a very lengthy process that can become very lengthy and tedious.

From the table above we see that all of the researched expert systems had a text based user interface, something that is not very common in the advanced computer systems of this current technological age. It also seems that they were all stand-alone programs and had to be installed on the computer before use. The fact all these systems need to be installed first before they can be run, means that there would be less of an instantaneous market penetration if they were to be deployed for public use.

The target market of the system plays a huge role in how the system will be developed; in order for the system to be usable, the potential users of the system have to be catered for in terms of the affordance of the system and the comprehensibility of the feedback offered by the system. A system like DENDRAL that is primarily for chemists was not designed to be used by a lay person.

Conclusion

This paper presents a brief compilation of previously developed expert systems and the causes and categories of Diabetes. Diabetes is a chronic condition with fatal consequences if not handled correctly and a large part of being able to effectively deal with this disease is firstly being aware of your diagnosis of Diabetes and also being equipped with the knowledge of how to successfully manage a life with the disease. The use of expert systems instilled with extensive medical knowledge to diagnose, educate and raise awareness on diabetes can make a huge impact especially in areas where access to professionals is difficult to come by.

The relative shortage of medical professionals in South Africa and the lack of sufficient medical knowledge of the public due to the low literacy levels is evidence that there is an opportunity and a need for the deployment of such a system. The successes of previous systems assure us that it is possible as it has been done before, in both the medical and other industries alike.

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