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Expert Systems in Healthcare

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Abstract An expert system (ES) is a computer program that has a knowledge base and a set of rules that infer new facts from the knowledge. Based on the knowledge base, the system is capable of making intelligent decisions. It is a branch of artificial intelligence that provides discipline-specific advice to the user. The ES captures scarce expert knowledge and render it archival. Its main goal is to replicate a human expert and replace him or her in a problem-solving activity. This paper provides a brief introduction to the applications of expert systems in healthcare.

Keywords expert systems, healthcare, artificial intelligence

Introduction

Expert systems are one of the most exciting and promising applications of computers. An expert system (ES) is designed to emulate the decision-making ability of a human expert. It encapsulates specialist knowledge of a particular domain of expertise and can make intelligent decisions. It is based on expert knowledge in order to emulate human expertise in any specific field. The basic concept behind ES is that expertise (such as highly skilled medical doctor or lawyer) is transferred from a human expert to a computer system. Non-expert users, seeking advice in the field, question the system to get expert's knowledge [1].

The healthcare system is becoming increasingly more complex and unmanageable. There is a need for tools such expert systems that can store knowledge and reason with medical expertise taken from a number of experts. When patients seek the help of medical experts, they do so for diagnosis and treatment of their various health problems. Expert systems can be employed in healthcare as complementary tools [2].

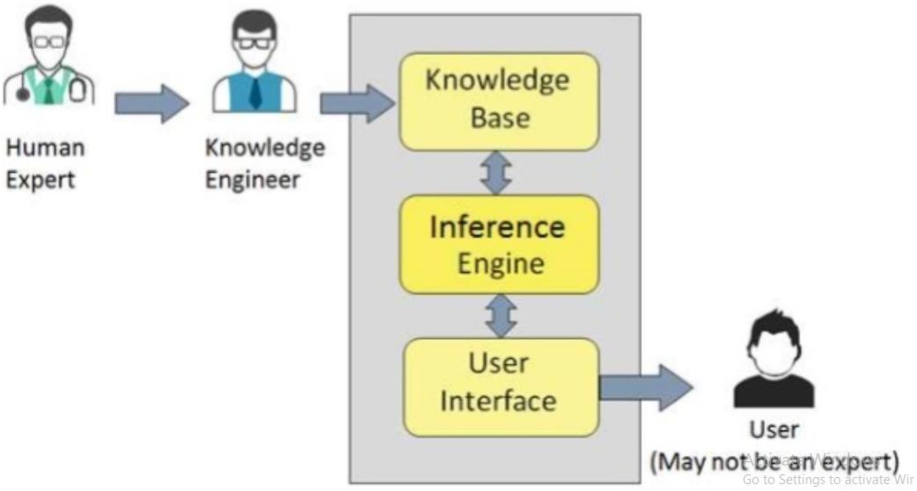

Figure 1: Structure of an expert system [3]

Expert Systems

An expert system, or decision support system, is a computer system that emulates the decision-making ability of a human expert. It acts in all respects like a human expert, using human knowledge to solve problems that would require human intelligence. It is a typical example of a knowledge-based system.

An expert system is typically shown in Figure 1 [3]. The figure shows that an ES consists of three main components: (1) knowledge base, (2) problem-solving and inference engine, (3) human-machine interface. Thus, an ES is an intelligent computer program that accepts input trough the user interface and uses knowledge in the knowledge base to make logical decisions through the inference mechanism. The knowledge base (long-term memory) is where the experts' knowledge is stored. The knowledge base consists of a set of IF…THEN rules, facts, and heuristics. We recall the popular saying: Knowledge is power. Problems cannot be solved without detailed knowledge of the problem and how it will be solved. It is the job of a knowledge engineer to incorporate expert knowledge in the ES by writing the necessary software. The inference engine draws logical conclusions (inferences) based on the information available in the knowledge base. It is the software that provides means of interpreting command and accessing the knowledge to solve a given problem.

An expert system without knowledge base is known as a shell. The inference engine is regarded as brain because it provides the ways for reasoning about information in the knowledge base. Inference can be performed using semantics networks, production rules, and logic statement. The interface provides interactive communication with the user, get information, and display ES recommendation. With an intelligent interface, a user of ES solves problems on the basis of relevant information.

When applied to healthcare, a medical expert system is an intelligent system that accepts patients' information through the system's user interface and uses the knowledge in the knowledge base through the inference mechanism to give diagnosis, and drug prescriptions to the patient [4].

Expert systems are different from other computer systems or other knowledge-based systems in the following ways [5]:

- They perform complex tasks like professional experts.
- They emphasize problem solving strategies.
- They can handle both symbolic and numeric logic.
- They provide some reasoning activities based on input.
- They provide for incomplete or uncertain data.
- They justify their conclusions.
- They follow human consultation paradigm.

Special declarative programming languages like LISP, PROLOG, and OPSS are used in developing ESs. An ES can be run on a PC [6]. Two popular approaches for ES are forward and backward chaining. In forward chaining, searching for a solution begins with some condition and then moves toward some conclusion to reach an ultimate goal. Backward chaining figures out if a stated goal is satisfied by starting with the THEN clauses and backing up to the IF clauses.

As expert systems evolved, many new techniques were incorporated into various types of inference engines. These include [7]:

- *Truth maintenance:* These systems record the dependencies in a knowledge-base so that when facts are altered, dependent knowledge can be altered accordingly.
- *Hypothetical reasoning*: In this, the knowledge base can be divided up into many possible views, a.k.a. worlds. This allows the inference engine to explore multiple possibilities in parallel
- *Uncertainty systems:* The real world is characterized by uncertainty. Uncertainty is called for when an expert system must choose which piece of information is an appropriate answer to the specific problem at hand. Simple probabilities were extended in some systems with sophisticated mechanisms for uncertain reasoning such as Fuzzy logic.

Today, there are a large number of commercial expert system tools or shells currently available.

Applications in Healthcare

Expert systems are finding wide range of applications due to their capability to provide solutions to a variety of real life problems. They are widely used in healthcare, business, finance, engineering, and manufacturing. Expert systems have applications in different areas of healthcare field. The main goal of expert systems in healthcare is to assist and support physicians and nurses in making decisions. A typical healthcare expert system is shown in Figure 2 [8].

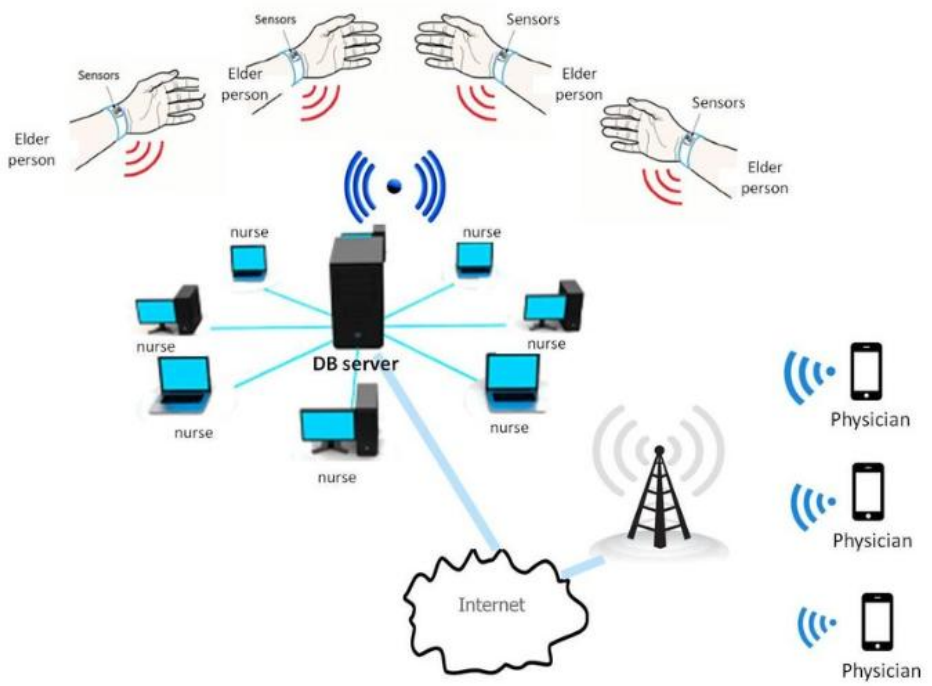

Figure 2: A typical healthcare expert system [8]

A variety of healthcare expert systems are now available and can help to function as intelligent assistants to clinicians, helping in diagnostic processes, laboratory analysis, treating patients, and teaching medical students and nurses. Since the 1960's the following experimental medical expert systems have been developed [9]:

- DENDRAL (Stanford University, 1967) deduces the chemical molecular structure of an organic structure from its formula, spectrographical data and magnetic-nuclear resonances.
- INTERNIST (Pittsburgh University, 1974) was a rule-based expert system for the diagnosis of complex problems in general internal medicine.
- MYCIN (Stanford University, 1976) was a rule-based expert system to diagnose and recommend treatment for certain blood infections (antimicrobial selection for patients with bacteremia or meningitis).
- CASNET (Rutgers University, 1960) was an expert system for the diagnosis and treatment of glaucoma.
- EXPERT (Rutgers University, 1979) was an extension generalized of the CASNET formalism which was used in creating consultation systems in rheumatology and endocrinology.
- ONCOCIN (Stanford University, 1981) was a rule-based medical expert system for oncology protocol management. It was designed to assist physicians in treating cancer patients receiving chemotherapy.
- CATEG05-ES is a successful expert system currently being used on a World Health Organization project to improve the reliability of psychiatric diagnosis.
- An expert system used in medical diagnosis is the Global Infectious Diseases & EpidemiOlogy Network, GIDEON.

The most popular medical ES is MYCIN, developed by E. H. Shortliffe at Stanford University in late 1970s. It offers medical diagnosis on illness [10].

Medical ES involves four interactive roles [11]: diagnosing, interpreting, predicting, and instructing. Medical ESs can provide an interactive support in clinical problems such as prediction of diseases (such as HIV and AIDS), medical examination, prevention of diseases, diagnosis of diseases, and providing patients with useful medical information. Expert systems can be used in expert monitoring, biometric data sensing, automatic diagnosis, and comprehensive diagnosis system. Other applications of medical expert systems include [12]:

- *Laboratory systems:* Clinical laboratories have proven to be a fertile domain for the use of expert systems.
- *Drug advisory systems:* There is a clear opportunity to design expert systems which will assist clinicians with the prescription of medications and selection of the most cost-effective treatments.
- *Signal interpretation:* The development of interpretive alarms for real-time clinical signals in areas like the intensive care unit.
- *Quality assurance:* There will be a need to check that the different types of knowledge-based systems remain up to date.
- *Education*: The need to continually educate both patients and healthcare professionals offers significant opportunities for automated assistance.

The current trend is moving away from large research based medical systems towards smaller, handy, practical systems, and healthcare application of newly emerging technologies such as big data, data mining, and wireless sensor networks.

Benefits and Challenges

Expert Systems offer some benefits in different areas in healthcare field. Expert systems offer a way of providing healthcare in a cost effective way by [13]: (1) Making expertise more accessible to other people. Expert systems can provide a convenient and economic way of spreading expert knowledge. (2) Relieving experts from routine tasks. Expert systems can perform routine expert tasks, while the expert can spend more time on the difficult analyses. (3) Providing a useful way for experts to develop and test ideas and theories. ES has shown some advantages such as utilization of experts' knowledge, gaining rare knowledge, more time for assessment of the decision, more consistent decisions, and shorter decision-making process [14]. Other advantages include consistency, availability, speed, accuracy, high performance, understandability, reliability, and high responsiveness.

Application of expert systems in the healthcare domain faces serious challenges. The vast majority of physicians view computer systems as alien, unwanted, and unnecessary addition to the conventional practice of medicine. Building expert systems to develop and test disease models is a challenging. Since expert system can be applied to different particular disciplines or domains, the costs of expert systems vary considerably and often include post-development costs such as training and maintenance. Expert system shells that are currently available usually require an experienced programmer to be used effectively. Shells are difficult to use and they fall far short of being able to adequately describe medical information. Updating the system can be very difficult. Other disadvantages include lack of emotion and commonsense and difficult maintenance.

Conclusion

An ES is artificial intelligence system that has been trained with real cases to perform complicated tasks and acts as a decision-support system. It is a computer application that combines computer hardware, software, and specialized information to imitate expert human reasoning. Expert systems can be used to train and practice clinicians and students on various medical tasks. For more information about expert systems, one should consult the book in [15] and ES-specific journals which include *Expert systems*, *IEEE Expert*, and *Expert Systems with Applications*.

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