Medical Diagnosis Advisor System: A Survey

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Abstract— **Aged patients need more healthcare efforts; it is quite obvious that diagnosing ailments during their initial phase can aid the treatment timely and appropriately. However, if attentions are not given to them on time, they can result in different kinds of health issues which may lead to death. Generally, Artificial Intelligence (AI) is increasingly employed for medical information science and medical expert systems in particular. Medical Expert systems are used to help the diagnosis operation of physicians. When the patient's signs and symptoms are computed, the system can give guidance that is needed (diagnosis, recommend treatments and drugs). Medical profession system utilizes information about the ailments and that of the patients to propose diagnosis. In this study, the authors reviewed works related to this area in order to assist in deriving the main characteristics and challenges with the prevailing systems. This study reviews and classifies knowledge base techniques using four categories: rule-based systems, case-based reasoning (CBR), knowledge-based systems, and fuzzy ESs/neural networks alongside with their applications on for different studies and medical problem areas.**

Index Terms— **Expert System, Knowledge Base, Medical Diagnosis, Rule-based System**

I. INTRODUCTION

As reported by the world population DB of the United Nations (UN) Population Division, in the next 45 years, the number of individuals in the world aged 60 years or older is anticipated to triple. This prolonged life expectancy along with an increased survival of acute diseases stimulated the necessity for providing better and effective healthcare services such as reliable and swift medical diagnosis and e-Health systems [1]. Artificial Intelligence (AI) is a part of computer science that deals with problem-solving and symbolic reasoning [2]. Expert systems (ES), a part of AI, are considered as software that simulates the behavior of a human expert [3]. An expert system's main intention is to give expert guidance and knowledge in specialized cases [4]. A medical expert system generates medical knowledge and programs [5]. It searches and uses pertinent data from their available KB and users to give suggestions [6]. This can surpass human expects because of Expert System [4], [7]:

- Reduction in errors.
- Reliability: (Do not become bored or weary and never rest).
- Will not ignore a solution.
- Intelligent DB (handling of numerous volumes of information).
- Quick response.
- Multiple expertises.
- Reproducibility: Several duplicates of an ES can be produced, but training new human experts is expensive and consumes time.
- Documentation: An ES can provide documentation of the decision process.
- Nevertheless, the drawback of an expert system is a lack of common sense. They are only fabricated for certain intents and not for others (cannot change with a changing environment) [5].

II. MEDICAL EXPERT SYSTEMS (MESS)

Since the 1980s, advancement of expert systems, both in practice and principle has obtained enormous development and success and illustrated its major value and importance [8]. A problem-solving expert system primarily provides useful information on managing patients' health care. A description of the medical condition (such as symptoms and signs) and a proposed solution (such as treatments and drugs) is provided via a user interface. A working storage is searched to identify information relevant to the problem and introduced a solution. Access to the selected information is available in either a full text or summary form, to help the user in evaluating the suitability of the proposed solution. An inference engine derives a recommendation from the knowledge base and the working storage data then introduce it to the user [9].

In the development of knowledge-based and medical expert systems, attention on particular is computed on the exploitation of fuzzy set theory and fuzzy logic as methodology implied the selection of patient's data, and inference procedures and medical knowledge presentation. These steps have various attributes that make them very appropriate for modeling vague information that is usually based on what medical concept being formed, interpreting the patient's condition, therapeutic decision-making and diagnosis. Firstly, medical entities which include signs, symptoms, test results, diagnoses, diseases, predication information items, and treatment proposals can be defined as fuzzy datasets. The intrinsic appropriateness of these entities will then be preserved. Furthermore, fuzzy logic provides reasoning techniques that are proficient in giving accurate and approximate conclusions [10].

The medical area may utilize more expert systems than any other areas. Dozens of advisory events have been reinforced to assist physicians in the diagnosis of a certain

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ailment and in some situations, suggest a solution. Studies in this field started at the end of 1960's, a number of medical diagnostic expert systems have been introduced which include MYCIN, EasyDiagnosis, PERFEX, ONCOCIN, and INTERNIST-I [8].

A. MYCIN

It is a part of the earliest rule-based expert system invented by Buchanan, Feigenbaum and Ted Shortliffe in 1970 at Stanford University to diagnose infectious ailments and assist doctors that are not experts in antimicrobial drugs to prescribe such drugs for blood diseases [11]. The drawback of MYCIN was that its perception origin is insufficient because it does not involve anything like a whole range of infectious ailments [11]. The diagnosis activity requires specimen culturing for isolating and identifying bacterial infections. It takes 48 h, thus, doctors had devised a quick way of solving the problems. MYCIN was effective because it can evaluate dosages accurately and manage interactions between drugs. It utilizes LISP that comprises of 450 rules for the implementation [12].

B. ONCOCIN

It is a rule-based expert system developed by Stanford University in 1981 for the purpose of oncology protocol administration. This was invented to assist doctors in the treatment of cancer patients collecting chemotherapy.

III. THE COMPONENTS OF EXPERT SYSTEM

According to Goodall and Turban et al., an expert system consists of some major and minor system components which are [4]:

1. User Interface: This provides proper information between the system and consulting physicians [12] which usually consists of the following components:

a. A Dialogue Structure: Knowledge elicitation was performed through interviews.

b. An Explanation Module: This is one of the most important features of an ES, it stimulates the system's activity indisputable by giving the result as well as the rules that were utilized to obtain the result modeling the user understands the way the system emerged to conclusion diagnosis.

2. Acquisition of Knowledge: This is the process of studying, organizing and acquiring relevant understanding from human experts (physician), books, specialized database and certificated websites. The knowledge can be peculiar to the challenging area or problem-solving processes [13].

3. Knowledge Base: This comprises of certain understanding in relation to the application area of the system [12]. There are various KBSs developed by different researchers all over the world. KBSs use reasoning methods such as Case-based reasoning, Rule-based reasoning, and Fuzzy logic to produce noticeable implementation in the field of diagnosis [14]. Selecting an appropriate representational schema relies on the nature of procedural control needed and level of closeness of the knowledge engineer with a method [15]. A rule-based system handles challenges from a distinct knowledge base that comprises rules and facts. It is certain that rule-based method of AI is an adequate method for every medical tasks and domain [14]. In which knowledge is presented in production rule form. A rule explains the activity that should be undergone if a symptom is noticed [15].

4. Working Storage (A blackboard): A database used to store a set of primary facts and facts arising from the inference engine that will be used by rules; perhaps with additional criteria such as degree of trust. The working memory is utilized through inference engine to obtain the details and collate them with the rules. The details may be collated to working memory by using some rules.

5. The Inference Engines: It obtains input inquiry and answers patient questions using user interface and data in the knowledge base (rule) and DB (fact) to acquire new findings (conclusion) on the problem to be resolved [3]. Two main methods involve are the forward and inference engine-backward chaining. The procedure is carried out in three phases: Execute, Select and Match. As the fact matches the rule, the rule fires and concludes. In case there is more than one rule, conflict resolution strategy is employed. In the conflict resolution strategy, the rule having a superior preference and recently computed into the database will be chosen. Thereafter, the selected triggered and items will be computed accordingly or evacuated from the working engine. Backward chaining is utilized when demonstrating certain conclusion [16].

The major components illustrated in Figure 1:

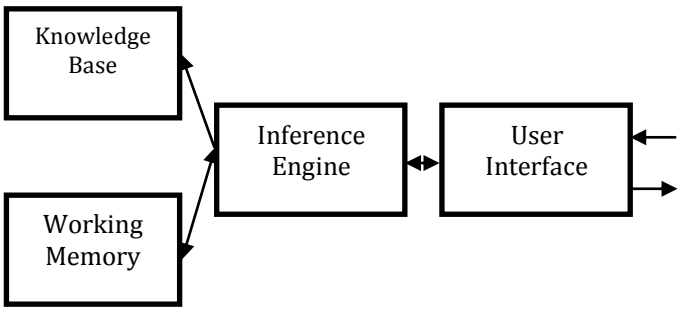

Figure (1): Components of the expert system

IV. KNOWLEDGE-BASED REASONING TECHNIQUES

A comprehensive survey of different books, journal articles, conference papers, and thesis are reviewed to understand the principles, techniques, and tools of knowledge-based systems. This paper reviews and classifies knowledge base techniques using four categories: rule-based systems, case-based reasoning (CBR), knowledge-based systems, and fuzzy ESs/neural networks alongside with their usage for several kinds of studies and medical problem fields.

A. Rule-based Systems (RBSs)

Rule-based systems are the easiest kind of artificial intelligence. Knowledge is represented in the kind of production rules rather than presenting it in a stationary and declarative way. Defining rule-based system relies mostly on expert systems that simulate the cognitive behavior of human

expert in resolving a knowledge-intensive challenge [17]. Rule-based models are adequate for fields whereby knowledge can be presented in thumb or heuristics rules form. This method is adequate for diagnostics and classification challenges [18].

Rule-based systems possess two demerits; larger training set is mostly not needed, and since the expert's thinking is directly identified, the way it thinks about challenges is known. They possess demerit that makes knowledge acquisition level difficult [19]. Table1.

Table (1): Rule-based System

Authors	Rule-based systems Techniques Disease diagnosis Evaluation and result
Tagel, A (2013) [13]	**"Knowledge-based system for pre-medical triage treatment at Adama University"** rule-based reasoning approach KBS for pre-medical triage treatment The performance of the system is evaluated by using predictive validation techniques with twenty test cases. The results indicate that the prototype is about 80% accurate
Santosh, P, P Dipti and M Indrajit (2010) [6]	**"An expert method used in the diagnosis of human ailment"** The system is rule-based system and causes inferences with signs for knowledge representation. Developed an expert system for diagnosing human ailment A trained expert would determine the status of the diagnosis carried out by the system.
Eugene Roventa and George Rosu (2009) [20]	**"The Diagnosis of Some Kidney ailments in a small PROLOG Expert System"** Rule-based expert system Kidney ailment This system comprises understanding about of 27 kidney ailments, however, experimental results are not reported.
K.Abdelhamied, et al. (2006) [21]	**"A rule-based expert system used in solving quick challenges amidst crowded out-patients' clinics in Egypt"** Rule-based expert system Major and minor diseases The system comprises about 300 minor and major ailments. It examined within 10 outpatient clinics, however, experimental results are not reported.
Solomon Gebremariam (2013) [22]	**"A self-learning knowledge-based system for treatment and diagnosis of diabetes"** Rule-based expert system Diabetes Disease This system produced information on patients and physicians to ease the treatment and diagnosis of diabetes. The system performance was 84.2%.
Jimmy Singla (2013) [23]	**"The diagnosis of some lung ailments in a PROLOG expert system"** Rule-based expert system Lung Diseases The expert system comprises 32 lung ailments and the system possesses about 70% precision.
Ahmad A, Al-Hajji (2012) [24]	**"Rule-based expert system for symptom and diagnosis of neurological infections"** Rule-based expert system Neurological disorders This expert system assists the patients in getting the needful information about different kinds of infections attack on them because of disorders in their nervous system. No factors were redeemed.
Samy S. Abu Naser and Mohammed A. Al-Nakhal (2016) [25]	**"A ruled-based system used for diagnosing ear ailment and the treatment"** Ruled based system Ear problem diagnosis Ear ailments were grouped into three categories: a- Inflammation in the inner ear b- Middle ear challenges c- External ear challenges
Jael Gudu and Alex Muumbo (2012) [26]	**"Development of a medical expert system as an expert knowledge sharing tool on treatment and of hypertension amidst pregnant women"** Rule-based system Treatment and diagnosis of hypertension amidst pregnant women The system was examined on a correlatively little population. The results reflected that the system could be used in the proposed domain (a hospital) through the focused users, nevertheless, training is required for the users. The system was easy to use, fast and for conveying diagnosis. For instance, the diagnosis of pregnancy

B. Knowledge-based System (KBESs)

KBESs are system operations targeted to proceed as an expert in solving a challenge in a certain area. The system utilizes an understanding of the environment in restraint technique for obtaining solutions. Since the knowledge base is an essential part, nevertheless, completely comprehended section of a KBES, the knowledge-based character is mostly not utilized. Therefore, the terminology of the expert system and the KBES can be used interchangeably [18]. Table2.

Table (2): Knowledge-based System

Authors	Knowledge-based Systems Techniques Disease Diagnosis Evaluation and Results
S. Ali et al. (1999) [27]	**"Graphical Knowledge-Based Protocols for Chest Pain Management"** Knowledge-Based System Chest pain This expert system provides adequate clinical instruction and conclusively in organizes pilot experiment in the emergency and accident sections of the national university hospital. However, experimental results are not reported.
John G. Holmen and Anthony H. Walff (1988) [28]	**"An expert driver for oliguria occurring on the intensive care unit"** Knowledge-Based System Oliguria occurring on the intensive care unit This system provides information on oliguria occurring in the intensive-care section. However, experimental results are not reported.
Freasier, R.E. et al. (1988) [29]	**"Evaluation of primary coronary arterial stenosis through a knowledge-based system"** Knowledge-Based System Predominant coronary arterial stenosis This system evaluates the primary site of the predominant stenosis. Based on the prevailing production rules, the system mostly identified the portion of coronary artery stenosis in over 90% of the available patients.

Samy S. Abu Naser and Abu Zaiter A. Ola (2008) [30]	**"An expert System used in eye diagnosis and eye diseases through CLIPS"** Knowledge-based system Eye diseases The suggested system can assist patients and doctors in obtaining expert suggestion, interactive training tool and decision support system. Some doctors and patients analyzed the system and reported a significant feedback. However, no factors were evaluated on this expert system.
Samy S. Abu Naser and Suheir H ALmurshidi (2016) [31]	**"A knowledge-based system for diagnosing neck pain"** Knowledge-based system Neck diseases diagnosis A preliminary test was carried out by patients suffering from neck pain problems. They are satisfied and very comfortable with it.
Samy S. Abu Naser and Rami M. AlDahdooh (2016) [32]	**"Diagnosis of lower back pain expert and treatment system"** Knowledge-based system Diagnose low back pain intensity A group of students in Medicine College voluntarily accepted to participate in testing the expert system. They were satisfied with the outcome of the suggested Expert System and they were comfortable using the system.
Samy S. Abu Naser and Ali O. Mahdi (2016) [33]	**"A suggested expert system for diagnosing foot diseases"** Knowledge-based system Foot diseases diagnosis The proposed foot diagnosed diseases expert system was evaluated using Medical students. They are pleased with the outcomes.

C. Case-based Reasoning (CBR) Expert System

Case-based reasoning (CBR) is the method of resolving new difficulties depending on the resolution from previous problems. The inference engine in CBR systems consists of (Adaptation, retrieving and testing results). It searches the memory for cases that resolved problems similar to the present one and then adapted to suit the current problem. Then, the solution is tested and added to the memory if it was successful. CBR is a technique for solving problems, human learning and computers as the expert systems depend on expert reasoning and expertise capacities for a particular part of the responsibility. Expert systems and CBR are correlated study areas [34]. Table3.

Table (3): Case-based Reasoning Systems

Authors	**Case-based Reasoning System** **Techniques** **Disease** **Diagnosis** **Evaluation and Results**
Stefania M. et al. (2003) [35]	**"Integrating model-based decision aid in a multi-modal reasoning system for controlling type 1 diabetes"** Model-based, rule-based and CBR reasoning Type 1 diabetes The system has been tested both on triggered on patients' information observed amidst the telemedicine project M^2 DM. The model examined using a three-step process. They obtain encouraging results
Subhagata Chattopadhyay et al. (2013) [36]	**"A Case-Based Reasoning system for complex medical diagnosis"** Case-Based Reasoning and K-Nearest Neighbor (KNN) Premenstrual syndrome (PMS) and complex medical diagnosis The experiment results show that the proposed apparatus performs well and its diagnostic precision level is acceptable to the medical doctors
Abdel-Badeeh M. S. et al. (2005) [37]	**"A Case-Based Expert System for Supporting Diagnosis of Heart Diseases"** Case-Based Reasoning and K-Nearest Neighbor (KNN)/Induction Heart Diseases Diagnosis Cardiologists examine the performance of the system through practical checking for 13 new situations when the system followed the estimation of adequate diagnosis. The results showed that the KNN is better compared to the induction technique as the retrieval precisions were 100 and 53.8%, respectively
Abdel-Badeeh M. S. (2007) [38]	**"Case-Based Reasoning Technology for Medical Diagnosis"** Case-Based Reasoning and K-Nearest Neighbor (KNN)/Induction Cancer and heart diseases diagnosis The knowledge consists of actual 70 cancer patient cases and 110 cases for 4 heart diseases. The results showed that the KNN is better compared to induction technique in regenerating process
Shahina B. (2009) [39]	**"A Case-Based Reasoning System in the diagnosis of person's sensitivity to Stress in psychophysiology"** Case-based reasoning and fuzzy techniques Psycho-physiological diagnosis and treatment plan The evaluation of the system depends on the dense relationship with measurement and experts from 24 individuals The result indicates system satisfaction of the expert

D. Fuzzy based expert system

Fuzzy logic is one of the soft computing techniques that adopted in medical diagnosis expert system due to its capability to handle contradictions ambiguities and uncertainties of information. The main merit of fuzzy expert systems is that major regulations can comply with the language that the expert can comprehend other than computer language; communication between knowledge engineer and the expert is excessively minimized. Another benefit is the possible capacity of rule-based expert systems in learning through the generation of new information and new rules to the expert knowledge database [19]. Table4.

Table (4): Fuzzy/Neural-based System

Authors	**Fuzzy/Neural -based Systems** **Techniques** **Disease Diagnosis** **Evaluation and Results**
Dipanwita, B. et al. (2011) [40]	**"Disease diagnosis system"** Knowledge representation they used is production rule and a neural network Intelligent medical system in the diagnosis of common diseases. The developed system exhibits satisfactory results
Mohammed A. K. et al. (2011) [41]	**"Design and implementation of fuzzy expert system of back pain diagnosis"** Fuzzy expert system Back pain disease This system is analyzed by utilizing the clinical

	information of 20 patients with differed back pain diseases and 90% accuracy was achieved.
Qeethara K. AI-Shayea (2011) [42]	**"Artificial neural networks in medical diagnosis"** Artificial neural network Acute nephritis disease, heart disease 99% accuracy was obtained when diagnosed with acute nephritis ailment. 95% precision was attained when diagnosed with heart disease through the feed forward back propagation network.
Obi J.C. and Imianvan A.A. (2011) [43]	**"Interactive neuro-fuzzy expert system for diagnosis of leukemia"** Neuro-Fuzzy Expert System Leukemia This expert system can predict patient's current situation in relation to leukemia. However, no factors were evaluated on this expert system.
Chang S. L. and Mei H. W. (2011) [44]	**"A fuzzy expert system for diabetes decision support application"** Fuzzy expert system Diabetes decision support The suggested fuzzy expert system can perform efficiently for diabetes decision support application. The proposed method achieves the 91.2% accuracy for "slightly old" peoples and 90.3% accuracy for "slightly young"
Ismail S. et al. (2003) [45]	**"A fuzzy expert system design for diagnosis of prostate cancer"** Fuzzy expert system Prostate cancer diseases The results indicate that it was adequate for learning and testing process for the medicine students
M.H. Fazel Zarandi et al. (2010) [46]	**"A fuzzy rule-based expert system for diagnosing asthma"** Fuzzy expert system Asthma diseases The system evaluated using 53asthmatic and 53 non-asthmatic patients for a Cut-off value 0.7, reinforcing the specificity 100% and sensitivity 94%

V. CONCLUSION

For the last twenty years, numerous contributions have been recorded in health sector using expert systems. The medical expert system will have an imperative role in the healthcare system. This paper reviews and classifies knowledge base techniques using four categories: rule-based systems, case-based reasoning (CBR), knowledge-based systems, and fuzzy ESs/neural networks alongside with their utilization for different study and medical problem fields. Most of the researches are implemented for specific domain area.

Different evaluation techniques are used in different studies. Several studies have examined their medical expert systems in hospitals using different parameters like accuracy and sensitivity. The value of these parameters depends on the knowledge base that has pertinent knowledge. Building such KB depends on knowledge acquisition stage, which is the process of acquiring, organizing and studying relevant knowledge from human experts (physician), books, specialized database and certificated websites. Therefore, the performance of the expert system relies on these parameters. One can improve the execution of medical expert system via using soft computing methods such as an artificial neural network (ANN) and fuzzy logic (FL). In order to increase the accuracy of the diagnosis process, the hybrid approach is used, which is the fusion of FL/ANN.

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