International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:14, No:12, 2020

Rule-Based Expert System for Headache Diagnosis and Medication Recommendation

Noura Al-Ajmi, Mohammed A. Almulla

***Abstract*—**With the increased utilization of technology devices around the world, healthcare and medical diagnosis are critical issues that people worry about these days. Doctors are doing their best to avoid any medical errors while diagnosing diseases and prescribing the wrong medication. Subsequently, artificial intelligence applications that can be installed on mobile devices such as rule-based expert systems facilitate the task of assisting doctors in several ways. Due to their many advantages, the usage of expert systems has increased recently in health sciences. This work presents a backward rule-based expert system that can be used for a headache diagnosis and medication recommendation system. The structure of the system consists of three main modules, namely the input unit, the processing unit, and the output unit.

***Keywords*—**Headache diagnosis system, treatment recommender system, rule-based expert system.

I. Introduction

EXPERT systems use artificial intelligence to model decisions similar to those made by experts in the field. Unlike decision support systems that provide several options from which the user may choose, expert systems convey the best decision based upon criteria that experts would use [5]. Hence, rule-based expert systems have been in use in several industries, due to their great advantages and practical efficiency. Recently, dedicated researches [2], [4], [9] investigate using them to assist physicians in making complex medical decisions in real-time. Such tools preserve the human knowledge and can assist and provide guidance for young doctors, healthcare practitioners and medical students. These systems excel in diagnosing diseases and in recommending the proper treatment as well.

In this work, we propose a backward rule-based expert system for the diagnosis and recommend treatment of headache. This universal chronic disease attacks millions of people around the world. There are over 150 different types of headaches, but in this research, we chose the common types of headaches including migraine headaches, tension headaches, cluster headaches, sinus headaches and rebound headaches. In year 2000, Robbins and Lang identified about a dozen major types and more than 60 subtypes of headaches [11]. The vast majority of which are either migraine headaches or tension headaches, which many people get from time to time, and to a lesser extent, cluster headaches.

A study asserted that "in order for patients to benefit from appropriate therapies, accurate diagnosis of headaches is required especially in migraine cases. When non-experienced physicians fail to ask the right questions, they may misclassify the type of headache or may inaccurately prescribe the medical treatments". This study also reported that, "the documented history is inadequate to exclude the diagnosis of migraine in two-thirds of cases in which a diagnosis of non-migraine headaches was made" [8]. Other studies confirmed that migraines are mistakenly classified as tension headaches [2], [6].

Our proposed system can diagnose the following major types of headaches (migraine, tension, and cluster) according to the report released by the Classification Committee of the International Headache Society (IHS) in 2018 [12]. In addition, the system can diagnose two common subtypes of headaches which are rebound and sinus headaches. In 2019, a literature review of studies validating diagnostic and classification headache tools available for non-expert clinicians to classify common chronic headache disorders and they concluded: "We did not identify a tool validated in a primary care that can be used by a non-expert clinician to classify common chronic headache disorders and screen for primary headaches other than migraine and tension-type headaches" [13].

In 2018, the Headache Classification Committee of the IHS released their International Classification of Headache Disorders [12]. In this report, the committee discussed many types of headaches including those caused by headaches-medication overuse, non-headaches medication overuse as well as their diagnostic criteria.

In this paper, we propose an expert system that is capable of diagnosing different types of headaches and suggests either over-the-counter medications or prescribed medication. In order to escape the trap of misclassifying types of headaches, validating the accuracy of the expert system can be replaced by providing the source of the knowledge that was used in the decision-making process. Hence, in our system, each rule is tagged by the source from which the knowledge represented in this rule is obtained.

The remainder of this paper is organized as follows: Section II discusses the related work; Section III describes the proposed rule-based expert system; Section IV explores sample runs for different cases; and, Section V presents the conclusion and future work.

II. Related Work

Expert systems have various advantages that make them appealing to many professionals in several domains. In the medical field for example in 1988, McWilliams developed,

Noura Al-Ajmi and Mohammed A. Almulla are with the Computer Science Department, Kuwait University, Kuwait (e-mail: nora_alajmi@hotmail.com, almulla@cs.ku.edu.kw).

ESTA, an expert system to aid medical students in understanding medical concepts [9]. In 1999, Tsumoto suggested a medical decision support system that is based on a rule induction method [14]. The system was designed for headache diagnosis in outpatients and the result was acceptable when compared with a human medical expert. In the same domain, one year later, Filipe et al. have implemented "PSG-Expert", which is an expert system for the diagnosis of sleep disorders [4]; the authors followed the international classification of sleep disorders in their approach. This particular system was considered as an integrated environment for the development of diagnosis-oriented knowledge-based systems and as a graphical representation of key concepts such as knowledge acquisition, knowledge representation, reasoning explanation, and knowledge-based validation.

Al-Ajlan has constructed two medical expert systems HDP (Heart Diseases Program) and PUFF (Pulmonary Function System) [1]. These systems played a significant role in assisting healthcare professionals in diagnosing and giving treatment recommendations. Sivakrithika et al. have developed a useful medical image diagnosis system [15]. Their study was about developing an accurate data mining architecture to detect cancer at very early stages, which increases the probability of successful cure. The proposed cancer diagnosing system used soft computing techniques, namely fuzzy and GNP for discretizing the feature values extracted from the images for the mining association rules [3]. The accuracy of the system was 83% in classifying unknown images, which indicates an efficient performance of the diagnosis system.

III. System Description

In this section, we present the details of the proposed system. The main objective of this system is to assist doctors, healthcare practitioners and medical student in their jobs. Unlike other e-business and commercial applications, the headache diagnosis and recommender system preserves the valuable knowledge of physicians in a knowledge-base where it is possible to retrieve it whenever needed.

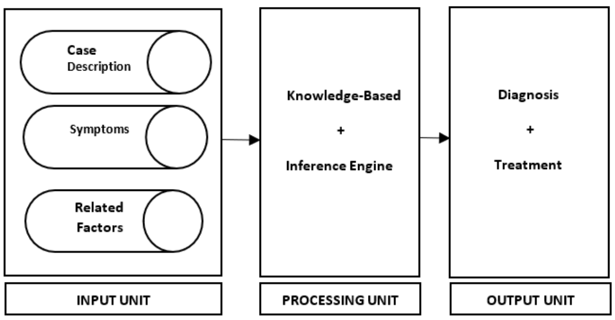

Fig. 1 The Structure of Rule-Based Headache Diagnosis and Medication recommender System

Expert systems may improve the process of disease diagnosis and treatment recommendation for headache. Our proposed system would eliminate any suspicion regarding a specific condition or symptom, since the knowledge is stored and maintained in the system at all times. Our diagnosis and recommender system is a backward rule-based system that is written in C programming language. It consists of three units: User Interface (Input Unit), Inference Engine (Processing Unit), and Explanation facility (Output Unit), as demonstrated in the structure of the expert system shown in Fig. 1.

The Input Unit takes a text file that contains all the facts related to the patient and the expertise (i.e. knowledge) of common headache types and subtypes. The system knowledge is collected from medical textbooks, doctors, and scientific research publications. The instructions to the expert system are written in a way that is similar to CLIPS commands [10], but not exactly the same. Precisely, each rule in the input file has a reference that indicates the source from which the knowledge in this rule was obtained. The user may verify the knowledge in the knowledge-base before using the system for medical diagnosis and/or treatment recommendation for patients. The input file organization is divided into three parts:

1. *Initial Diagnosis or treatment preference*: In this part, the user of the system defines the GOAL that represents his/her initial diagnosis of the headache type or the preferred treatment, whether it is medical or non-medical treatment. Note that medical treatments can be either prescribed medicine or over-the-counter medicine.
2. *Patient Symptoms and Related Factors:* The second part of the input file contains facts about the patient symptoms, demographic data, medical history, pregnancy (if applicable), and other related facts. These facts are stored in the Working Memory using ASSERT statements.
3. *Rules:* The last part of the input file contains the knowledge entered by the knowledge engineer in the form of rules. These rules can be used to diagnose the common five types of headaches recognizable by the system as well as rules related to different types of treatments (medical, non-medical, over the counter, prescriptions) for each type or subtype of headache.

The Processing Unit would apply the rules in the knowledge-base to the facts in the working memory to produce new facts. The Inference Engine of the system works in a backward reasoning manner starting from the defined GOAL by the user, until it reaches all related facts to it. Automatically, rules that can be fired are moved to the agenda to be processed depending on the rule-selection strategy. For this work, we have implemented the LIFO (i.e. Last-In-First-Out) control strategy. The process of manipulating the input data and making a decision is time efficient; it takes less than one minute. The last component of the system which is the Output Unit performs the patient's headache diagnosis and/or provides the recommended treatment for it.

IV. Sample Runs

In this section, we explore two sample runs for the Rebound headache to show how the system can be used by healthcare professionals. The first of which, corresponds to the headache type diagnosis, and the other case corresponds to the medical treatment recommendation for this type of headache.

A. Case 1: Rebound Headache Diagnosis

The user's initial opinion regarding this case is *Rebound Headache*.

(**defgoals** g1 (rebound_headache))
Then, the user enters all the patient's symptoms and other related factors as shown in the next ASSERT statement:
(assert (type unknown) (irritable_or_depressed)
(have_trouble_sleeping)

This statement indicates that the headache type of the patient is not yet known and this patient has the following symptoms: is irritable or depressed, has trouble sleeping. Before prescribing any medicine, the doctor wants to make sure if these symptoms are related to *Rebound headache* or no. The result of the program will be as shown in Fig. 2. Tagging the output subgoals by 1's means these subgoals were satisfied by the two fired rules r2-b2 and r1-b2 (shown in the Appendix) that support the user initial diagnosis (i.e. rebound headache) [7]. Tagging the subgoals by 0's means they were not satisfied.

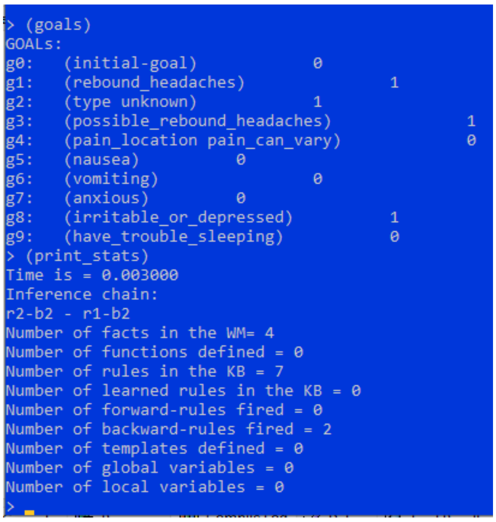
```
> (goals)
GOALs:
g0:   (initial-goal)            0
g1:   (rebound_headaches)               1
g2:   (type unknown)            1
g3:   (possible_rebound_headaches)                  1
g4:   (pain_location pain_can_vary)                 0
g5:   (nausea)          0
g6:   (vomiting)                0
g7:   (anxious)         0
g8:   (irritable_or_depressed)          1
g9:   (have_trouble_sleeping)           0
> (print_stats)
Time is = 0.003000
Inference chain:
r2-b2 - r1-b2
Number of facts in the WM= 4
Number of functions defined = 0
Number of rules in the KB = 7
Number of learned rules in the KB = 0
Number of forward-rules fired = 0
Number of backward-rules fired = 2
Number of templates defined = 0
Number of global variables = 0
Number of local variables = 0
>
```

Fig. 2 Output of Headache Diagnosis System

B. Case 1: Rebound Headache Recommendation

The next step is recommending an appropriate treatment for this patient. The user indicates to the system that a medical treatment is required but the preferred medicine should be over the counter not prescribed. For instance, the user would like to know if Aspirin is good for this case.

(**defgoals** g1 (rebound_headache))
Then, the user enters all the patient's symptoms and other related factors as shown in the next ASSERT statement:
(assert (type unknown) (irritable_or_depressed)
(have_trouble_sleeping)

The listed fired rules in the Inference chain indicates that prescribing *Aspirin* is appropriate for rebound headache, tension headache, and migraines (the details are in Appendix A). Subsequently, the user will be confident about his/her diagnosis for the type of headache and will prescribe *Aspirin* without any hesitation.

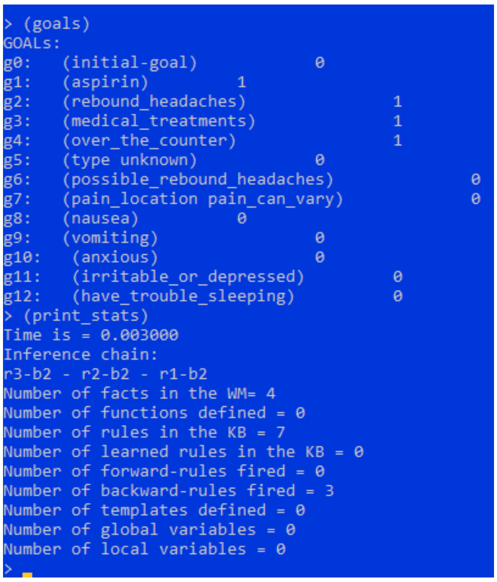
```
> (goals)
GOALs:
g0:   (initial-goal)            0
g1:   (aspirin)         1
g2:   (rebound_headaches)               1
g3:   (medical_treatments)              1
g4:   (over_the_counter)                1
g5:   (type unknown)            0
g6:   (possible_rebound_headaches)              0
g7:   (pain_location pain_can_vary)             0
g8:   (nausea)          0
g9:   (vomiting)                0
g10:   (anxious)                0
g11:   (irritable_or_depressed)         0
g12:   (have_trouble_sleeping)          0
> (print_stats)
Time is = 0.003000
Inference chain:
r3-b2 - r2-b2 - r1-b2
Number of facts in the WM= 4
Number of functions defined = 0
Number of rules in the KB = 7
Number of learned rules in the KB = 0
Number of forward-rules fired = 0
Number of backward-rules fired = 3
Number of templates defined = 0
Number of global variables = 0
Number of local variables = 0
>
```

Fig. 3 Output of the Treatment Recommender System

V. CONCLUSION & FUTURE WORK

It is obvious how the use of expert systems has a great impact on our life-style, especially, in the medical field. This paper briefly presented some examples that served physicians, healthcare practitioners and medical students efficiently in diagnosing and recommending therapy. Our study suggested a helpful medical application that is able to diagnose the type of headache and to recommend proper treatment to it. Although this system can be used anywhere, it can be more beneficial to those in developed countries where medical care is rare but highly needed. Fortunately, the system functionality allows it to be applicable for any other kind of diseases in its knowledge base, depending on the user's requirements of the recommender system. In the future, we plan to use this system for other widely spread diseases such as blood pressure and heart attacks. In addition, we plan to add certainty factors to the rules for reasoning with uncertainty.

APPENDIX

(**defgoals** g1 (aspirin))
(**breset**)
(**assert** (rebound_headaches) (medical_treatments) (over_the_counter))
(**deforule** r1-b2 (pain_location pain_can_vary) (nausea) (vomiting) (anxious) (irritable_or_depressed) (have_trouble_sleeping) => (possible_rebound_headaches))
(**defrule** r2-b2 (type unknown) (possible_rebound_headaches) => (rebound_headaches))
;;; Rebound_Headaches OTC_medical_treatments
(**defrule** r3-b2 (rebound_headaches) (medical_treatments)

(over_the_counter) => (aspirin))
(**defrule** r4-b2 (rebound_headaches) (medical_treatments)
(over_the_counter) => (ibuprofen))
(**defrule** r5-b2 (rebound_headaches) (medical_treatments)
(over_the_counter) => (acetaminophen))
;;; Rebound_Headaches non-medical_treatments
(**defrule** r6-b3 (rebound_headaches) (non_medical_treatments) =>
(limit_use_of_pain_relievers))
(**defrule** r7-b2 (rebound_headaches) (non_medical_treatments) =>
(minimize_caffeine))
(**brun)**
(goals)
(print_stats)
;;; **Sources**
;;; b2 = Headache Help_ A Complete Guide to Understanding
Headaches and the Medications That Relieve Them
;;; b3 = Kumar and Clark's Clinical Medicine

REFERENCES

[1] Amani Al-Ajlan (2007) Medical Expert Systems HDP and PUFF, Technical Report, Computer Science Department, King Saud University.

[2] Cady R., Dodick DW. (2002). Diagnosis and treatment of migraine. Mayo Clinic Proceedings 77:255-61.

[3] Sreekantha, D.K., Girish, T.M., and Fattepur, R.H. (2016). A Review of Applications of Expert Systems in Medical Sciences. 18th International Conference on Fuzzy Set theory and Applications. Paris, France, pp. 2063-2066.

[4] Filipe, Fred, J., Partinen, M., and Paiva, T. (2000). PSG- EXPERT– An Expert System for The Diagnosis of Sleep Disorders, Studies in Health Technology and Informatics, pp. 127-147.

[5] Hebda, T., Czar, P., and Mascara, C. (1998). *Handbook of informatics for nurses and health care professionals*. Menlo Park, California. Addison Wesley Longman.

[6] Kaniecki, RG. (2002). Migraine and tension-type headache: an assessment of challenges in diagnosis. *Neurology. 58*(9 Suppl 6):S15-20.

[7] Kumar, P., & Clark, M. L. (2013). *Kumar & Clark's cases in clinical medicine*. (3rd Ed). Elsevier Health Sciences.

[8] Maizels M. (2001). Headache evaluation and treatment by primary care physicians in an emergency department in the era of triptans. *Arch Intern Med. 161*(16)*:*1969-73.

[9] McWilliams, A. T. (1988). Introducing expert systems to medical students using esta, Expert System Teaching Aid. *Medical education*, *22*(2), 99-103.

[10] Riley, G. (1996). CLIPS: C Language Integrated Production System, NASA's Johnson Space Center, http://www.clipsrules.net/

[11] Robbins, L.D., & Lang, S.S. (2000). *Headache Help: A Complete Guide to Understanding Headaches and the Medications That Relieve Them.* Houghton Mifflin Harcourt.

[12] Olesen, J., Bes, A., Kunkel, R., Lance, J. W., Nappi, G., Pfaffenrath, V., ... & Welch, K. M. A. (2013). The international classification of headache disorders. *Cephalalgia*, *33*(9): 629-808.

[13] Potter, R.A., Probyn, K., Bernstein, C.J., Pincus, T., Underwood, M., & Matharu, M.S. (2019). Diagnostic and classification tools for chronic headache disorders: A systematic review. *Cephalalgia 39*(6) 761–784.

[14] Tsumoto, S. Computational Intelligence and Multimedia Applications, 1999 ICCIMA '99. Proceedings. 3rd International Conference pp. 212 – 216, DOI:10.1109/ICCIMA.1999.798531.

[15] Sivakrithika, V., Sengole Merlin, S., and Sugirtha, K. (2012). An Efficient Medical Image Diagnosis System Using Soft Computing Techniques, *Journal of Theoretical and Applied Information Technology 36*(2): 190-198.