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A Decision Support System for Polyuria Patient's Treatment Based on CLIPS Expert Systems

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Abstract

An expert system is a computer application that simulates the reasoning skill and performance of a human or an organization that has expert knowledge and experience in a specific area. Our goal was to design an expert system which could be useful for physicians to produce more accurate prescriptions for polyuria patients. In our paper, we first studied the logical rules that were needed to produce a prescription for polyuria patients and represented them in an antecedent/consequent model of rules that were capable of being used in an expert system. Afterwards we used a powerful expert system tool, CLIPS, to implement our proposed expert system and discussed parts and fundamentals of our expert system that were designed based on the studied rules. Since our expert system produced its prescription based on strict medical science instructions, our goal was to make the system be able to cooperate with physicians' experiences on polyuria patients. Further in our paper, we used the double-blind technique to evaluate our proposed expert system and compared its results with alternatives (physicians).

Keywords: Artificial Intelligence, Expert System, CLIPS, Polyuria, Prescription

1. Introduction

Considering the large number of known diseases, variety of existing drugs and patient with different conditions on age, weight and backgrounds, physicians can only keep a

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limited number of prescription states in their mind and require using reference books to produce the right prescription and calculate the usage amount of drugs in other situations. After diagnosis of the disease, physicians first need to select the right drugs among their various choices considering available types of that particular drug in the country and then required to calculate the usage amount of the drug with respect to patient's age and weight.

Due to variety of "drug usage amount" and "drug usage period" formulas, diseases and patients' conditions, physicians can only keep about two or three formulas in their mind to use in their calculations [1]. Some usage of drugs may cause some abnormalities in the patient's situation that is caused by drug conflictions and also the patient might have more than a disease at a time that each needs different treatments. This might lead to unwanted side effects [2] that need to be considered by the physician. It is even possible that through years, new side effects of a particular drug get discovered and its usage as a treatment to a specific disease gets banned.

Intelligent computer programs could be used to reduce these limitations and help physicians produce a better prescription. However, this requires the knowledge of logical rules applied on polyuria patients. Our goal in this paper by building logical rules for an expert system that produces prescription for polyuria patients is to resolve problems on prescribing and ease the process of treatment using computational techniques. In order reach such goal, following process have taken place:

1. Instruction: It is the science and techniques that a physician uses to treat a patient, represented in form of a set of rules.
2. Validity of rules: Retrieved rules have been evaluated and their validity ratios have been discussed.
3. Expertize and decision support: In our system, a suitable inference mechanism has been used which prefers the right prescription based on the existing rules.

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4. Learnability: In each step of the process, physicians have the ability to apply their own thoughts and in case of need, recommend a better treatment. This made it possible to combine physicians' experience with the existing knowledge in the system.

5. Usability in the physician's clinic: We have improved our system in accuracy, performance, usefulness and acceptability of its result so our polyuria treatment system could be used in physician's clinic and help in process of patients' treatment.

The rest of the paper is organized as follows. In Section II, we briefly discuss an overview of what Expert systems are and how do they work, Section III introduces a powerful tool for implementing expert system (CLIPS) and briefly discusses about its background. In Section IV, an overview of Polyuria definition is covered. Then in Section V, we define some of the common medical terms that are used in the rest of the paper.

Section VI discusses the design of the knowledge base of our prescription system and its relevance to Expert systems. In section VII Framework of our proposed system is clarified. Section VIII argues how our expert system works and in section IX, we evaluate and compare our proposed system with available alternatives (in our case, physicians) and finally in the conclusion, a brief overview of the paper is obtained and discussed.

2. Expert System

Expert system is a subdivision of Artificial intelligence and generally is defined as a computer program designed to model the problem solving ability of a human expert [3] that is proposed to perform in all respects like a human expert in a specific field.

Constructing an expert system is recognized as knowledge engineering and its experts are called knowledge engineers. The knowledge engineer should pick a knowledge representation and need to confirm that the computer can use the knowledge well enough by selecting from a minority of reasoning techniques. Typically such a system contains a

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knowledge base containing accumulated experience and a set of rules for applying the knowledge base to each particular situation that is described to the program.

Expert systems can be categorized from different points of view. It could be the advisory systems, the ones that recommend the direction; systems taking decisions without the help and human interference; criticizing systems the ones which on the basis of a particular problem and the predicted solution by a man, analyze and comment the particular reasoning and action way. It is important that there is a close cooperation between a system engineer and experts on those interest fields when constructing the appropriate expert system. Nothing can replace the knowledge and expert's experience [4].

Expert systems have many advantages over traditional computer applications and one could be the separation of knowledge from its processing which is a powerful feature of expert system that permits the reuse of existing code and greatly reduces the development time for other systems.

Although advantages of expert systems overs expert human beings are deliverance of permanent knowledge, ability of reproduction of the available skill and knowledge by just duplicating the computer database, steady and reproducible outcomes, reasonably cheap to work and sustain.

The structure of expert systems consists five main parts which are as follows:

1. Knowledge base: part of an expert system that contains the domain knowledge.
2. Working memory: part of an expert system that contains the problem facts that are discovered during the session.
3. Inference Engine: Processor in an expert system that matches the facts contained in the working memory with the domain knowledge contained in the knowledge base, to draw conclusions about the problem.

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4. Explanation facility: interpretability provider in expert systems.
5. Interface: Part of the system that interact with user.

Expert systems are designed to accomplish generic tasks on the basis of the problem type as illustrates in table1 [3].

Table1: Type of problems solved by Expert systems

Problem solving paradigm	Description
Control	Governing system behavior to meet specification.
Design	Configuring objects under constraint
Diagnosis	Inferring system malfunctions from observables
Instruction	Diagnosis, debugging
Interpretation	Inferring situation description from data
Monitoring	Comparing observations to expectations
Planning	Designing actions
Prediction	Inferring likely consequence of given situations
Prescription	Recommending solutions to system malfunction
Selection	Identifying best choice from a list of possibilities
Simulation	Modeling the interaction between system components

3. Clips

CLIPS is an expert system shell originally developed in 1984 by the Artificial Intelligence Section of NASA's Johnson Space Center and is written in C. CLIPS uses a forward-chaining inference strategy based on the Rete pattern-matching algorithm. The CLIPS shell provides the basic elements of an expert system [5]:

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Fact list and instance list: Overall memory for data

Knowledge-base: Covers all the rules

Inference engine: Controls overall execution of rules

A program written in CLIPS may contain rules, facts, and objects. The inference engine decides which rules should be performed and when. A rule-based expert system written in CLIPS is a program where the facts, and objects (if needed), are the data that stimulate execution via the inference engine. Fact [6] consists of relation name(a symbol field), followed with zero or some slot (also symbol field) and their relevant value.

4. What is polyuria?

Human body may be infected by different type of bacteria or viruses that may lead to dangerous diseases with different symptoms and some of these symptoms can be common among a number of diseases. Polyuria is one of these symptoms on human body that is common between dangerous diseases such as Diabetes and Tachycardia and non-risky diseases such as water intoxication and pregnancy polyuria. It is defined when a person produces abnormally large volume of urine about 2.5 to 3 liters per day.

5. Definitions

Before discussing more detail on the topic, we need to define some of the common medical terms that are used in the rest of the paper.

- Polyuria related diseases: there are several diseases that could cause a person's polyuria such as Diabetes, Addison, Lupus and etc. In this paper, we use the term diseases instead of polyuria related diseases.

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- General drug and their Commercial names: Generic drugs are the drugs that are well known and officially used in every country but might be called with a different name in each country that is their commercial name.
- Type of the drug: drugs are made in different types such as tablets, capsules and drops for different type of use.
- Consuming type of the drug: each drug could be consumed through different ways depending on patient's situation.
- Usage amount of the drug: amount of the drug patient need to use throughout a treatment.
- Drug usage period: the number of times a drug needs to be used in a period of time which is dependent to the drug itself, disease and patient's situation.

6. Logical prescription rules

Parts of a prescription are "name of the drug", "type of the drug", "consuming type of the drug", "usage amount of the drug" and "drug usage period". An example of a prescription is as follows:

Tab, Ranitidine 1mg

Oral 1N x 1T/Day

Cap, Amoxicillin 25mg

Oral 1N x 3T/Day

Tab, Tramadol 1mg

Oral 0.50N x 1T/Day

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By gathering information on the treatment approaches and evaluating them, we need to represent them in a way that computer can process. Most common technique to represent knowledge is “Rules”. Advantages on using Rules are simplicity, their use on defining the empirical relations, ability to adjust knowledge base, existence of various inference techniques and the non-linear inference engine however, there are some disadvantages for Rules and the main can be mentioned as the slow performance.

Based on the discussion above, we have used the Rules technique to represent our data and CLIPS to store and process the rules and implement the system.

Prescribing rules are divided into two main sections:

- First section that includes seven categories of standard rules is used to release a prescription for a patient. In brief, we discuss these categories using one sample from each.

A. Rules for categorizing patients age

(Patient (< age 2))
=>
(Patient (age “baby”))

B. Rules for categorizing patients weight for both genders.

(Patient (sex male) (< Weight 50))
=>
(Patient (weight ”thin”))

C. Rules to retrieve the right drug from Database for the chosen disease.

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(Disease (name ?DName)(drug ?Drug))
=>
(Assert (Diagnosis (drug (name ?Drug)))

D. Based on patient's situation and the seriousness of the disease, it chooses the right "type of the drug" and "consuming type of the drug".

(patient (age "baby"))
=>
(packet (drug "drop"))

E. Rules to check the confliction between drugs and patient's background.

(patient (background ?Disease))
=>
(conflict (drug ?Drug)(disease ?Disease))

F. Rules which select the "right usage amount" of the drug based on the patient's background and condition.

(patient (background ?Disease)(urgency "High"))
=>
(assert (drug (dosage "High")))

G. Rules to tune the suggested prescription based on patient's financial ability and availability of the drug.

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?f1<-(drug (availability "Low")(name ?drug))
?f2<-(instead (drug1 ?drug)(drug2 ?drug2))
=>
(retract ?f2)
(modify ?f1 (name ?drug2))

- And second section is related to particular conditions when physician, considering patient's conditions, need to change the flow of the system's prescribing method and inserts new rules into the system. This will likewise increase the accuracy of the system design for example:

(patient (urgency "High")(ability "Good"))
=>
(packet (drug "ampule"))

7. Framework of proposed system

Prescribing for polyuria patients is in a way that once patients visit the physician they will briefly describe their physical condition and whether or not they have had any illness background. In each visit, physician will check the symptoms and reasons that patients have visited him/her considering their physical condition. The physician will then recall his/her memory for diseases that match those symptoms since each disease has its own sign and symptoms [7], [8]. Then the disease(s) is chosen among the rest of diseases.

However prescribing has several factors [9], [10] and each is very important on its own, not considering any could have great changes on the prescription which might be dangerous for polyuria patient. Chosen drugs are tuned based on patient's condition such as

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pregnancy, breast-feeder, liver and kidney diseases, allergy and etc. physicians should consider patient's background and then choose the right prescription and "consuming type of the drug" based on "type of the disease", "urgency of disease" and patient's age.

After selection of the right consuming type for the drug, physicians choose the right type of the drug considering it's availability in stores however, patient's ability would also influence the "consuming type of the drug". For each age range and considering patient's weight and urgency of their disease, physician will select the right usage amount and usage period for the drug. The proposed polyuria prescription system is divided into three parts which are as follows:

1. Overall structure: This software at first will receive information about patient's details and background and assigns a new file to them. After diagnosis a disease by physician, system begins to produce a prescription based on its knowledge database. Also physician can use the expert system to produce an intelligent prescription in such way that system will compare the patient's information and the given diagnosis by the physician.

   In case of not finding any similar data in the knowledge base, the physician's diagnosis will be selected, otherwise, the system's decision will have higher priority. Of course in the end, selection of the right prescription will be on the physician to decide. The expert system uses its inference engine and a set of rules on medical treatments to produce a prescription intelligently. The proposed expert system consists of parts User Interface, Knowledge Base, Inference engine and Fact List.

2. Prescribing Knowledge base: After receiving the patient's information which is entered by the physician, name of the diagnosed disease is asked from the physician and once receiving the name of the disease, the related code for the disease is retrieved from the knowledge base together with name of the drugs and information which are

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used in treatment of the disease. In this state, all the factors such as the availability of the drugs in the country (such as pill, ampule and etc.) which were entered in the knowledge base, types of drugs, their dosage and required usage amount for a patient are considered one by one and the prescription is released accurately and whole. Chosen drugs are checked based on patient's background therefore the system will be able to release notice messages in case of conflictions.

3. Inference engine: This part has the duty to choose the fittest rule compare to data in the working memory from knowledge base. Entire input data in the system are entered through system's pages that include patient's information forms, patient background form and patent's visit history forms and also through working memory file. Inference engine selects the rules on order and checks their IF part. In case that based on the data in the working memory, a related rule's conditions get satisfied, this means the rule will get selected and its THEN part will be extracted and the results will be kept in the TEMP Working Memory as temporary results.

   Since these results are not kept in the original Working Memory, while runtime would not have any influence on the rest of rules. This means all the rules are fired once with equal conditions and all their output result are stored in a temporary memory which is called TEMP Working Memory. After all rules are fired and their results are stored in the TEMP Working Memory, these results are transferred into the original Working Memory. Now in case of any changes in the original Working Memory, the entire rules are checked based on those changes and fired if their conditions satisfy. This process will repeat until nothing changes in the original Working Memory and system reaches a stable mode.

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8. How does the system works

System data is divided into three main parts, Knowledge Base, Working Memory and Rules.

- Knowledge Base: The entire basic medical information which is needed in order to release a prescription is stored in the Knowledge Base as a list of facts. These facts can be including items such as:
  - Patient's Personal Detail
  - Patient's Background
  - Pregnancy or Brest-Feeder
  - Existence of any allergy
- Working Memory: Data in original Working Memory are also divided into two categories. However, we have used a Temporary Working Memory that will be discussed further on.
  - First Working Memory: Part of the data which are entered through the system Q&A part.
  - Second Working Memory: Since not all Questions might be asked or answered correctly, Second Working Memory is the memory that stores the data which are entered manually such -as: Patient's consciousness and Patient's urgency. Also in this part, it is possible to modify the data which are kept in the first working memory.
  - Temp Working Memory: Consist of output data given from rules that have got fired after being selected by inference engine. After all rules are fired

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and their results are stored in the TEMP Working Memory, these results are transferred into the original Working Memory

- Rules: This part includes rules for our expert system that is stored in a ".CLP" file.

In order to improve the accuracy and inference strength of the system, a number as a coefficient is definable that is known as "Certainty Factor (CF)" and can be in range of -1 and 1. There are two approaches to use CF in a system which are:

- Using CF as a priority number: This approach is used when a group of known assumptions produce different results that may set different values to a variable. CF is used as a priority number for each rule that stops the rules with lower CF to be fired and resolves the problem of rule confliction.
- Using CF in probabilistic functions: This is the second approach of using CF in cases where result of a group of known assumptions set different values to a variable. With the difference that each value will be paired with its Certainty factor (CF) and then kept in the memory. Using a specific function that receives a group of CF values, an output CF will be calculated and its paired value will be kept in the variable.

We will discuss the evaluation results of these two approaches and other available methods in the next section.

9. Evaluation

In this section, we evaluate the implemented system by gathering data from seventy three patients with variation on age, weight and background and entering the data into the system. Knowledge of the system has been collected from five physicians in the field of urology. Afterwards using three available methods that were implemented and will be

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discussed, we produced prescriptions for our polyuria patients. These three implemented methods are:

1. Polyuria Database: This is the classical method to search for the right prescription using databases that keep the information of diseases. Afterwards, when the physician diagnoses the cause of patient's polyuria and enters the disease name to the system, the Key ID of that disease is found and database is searched for any matches. A prescription output will then be resulted.
2. Expert System 1: This implemented method is an expert system that uses its knowledge base and inference engine to produce a prescription and uses Certainty Factor coefficient as a priority number which is explained in the previous section.
3. Expert System 2: Just like previous implemented method with the difference on the usage of Certainty Factor in a probabilistic function. This method is briefly discussed in the previous section.

In order to evaluate these methods, their output prescriptions were compared to five other physicians (evaluators) while the system has not experienced our gathered data in the training phase. In other word, our system was evaluated in a double-blind approach. Number of unacceptable results are counted and shown on Figure 1.

It is important to note that the difference between our expert systems and evaluators' opinion has occurred based on their difference on studies and knowledge. It is clear that by applying the knowledge of our evaluators to our expert system, we can decrease the difference as small as possible.

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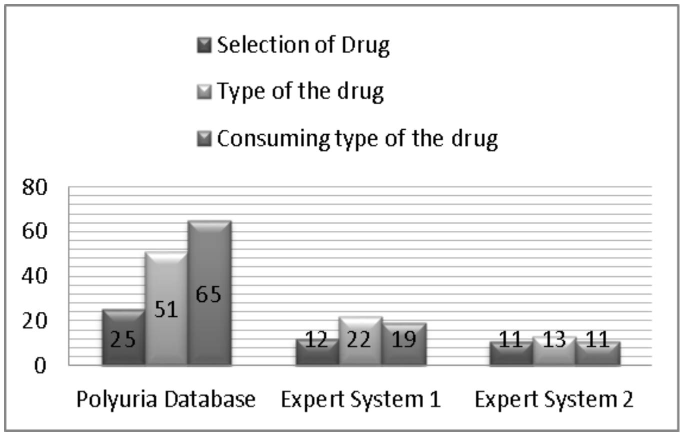

Figure 1. Comparison of method with evaluators' opinion

Based on physicians' opinion we have concluded that important parts of a prescription are "selection of drug", "type of the drug" and "consuming type of the drug". These three parts do not have the same level of importance in a prescription. In Table 2, their weights of importance are shown.

Table 2. Weight of importance of parts in a prescription

Part	Weight
Selection of Drug	5
Type of the drug	3
Consuming type of the drug	2

Using the weighted average technique, three importance parts of a prescription (Table 2) are combined with comparison of the result of our three methods (Figure 1) and the result are shown in Figure 3.

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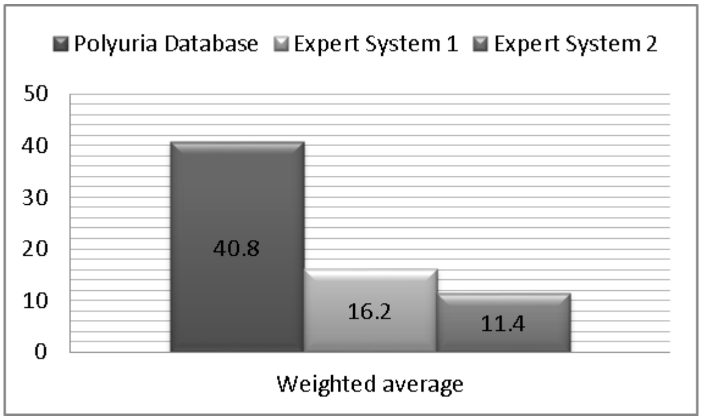

Figure 2. Comparison of weighted average of methods

As it is observable, results of "Expert System 2" have the minimum error compared to the rest followed by "Expert System 1" and "Polyuria Database".

Conclusion

Based on what has been mentioned in the first section, the main goal of producing rules and intelligent system was to resolve the problem of difficulty in producing a prescription by using computational techniques and methods. To reach such goal, knowledge and skill that a physician uses to treat a patient are represented in form of rules and facts and are stored in an intelligent system. These rules are the fundamentals to produce a prescription for diseases that cause polyuria. In this system physician can also force his/her opinion to the system and in case of difference with the system's prescription, new rules can be entered into the knowledge base to combine physician's medical experience and system's current knowledge.

As the results of the section IX shows, we can point out that our proposed system results about 92% acceptable which proves the correctness of our implementation of inference

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engine and knowledge base in the system. Our system could also be useful for medical students as a decision support system.

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