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Fuzzy Logic Expert Systems in Hospital: A Foundation View

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Abstract: Most of the prescribing and dispensing software systems assessed did not offer consistently useful, relevant support to GPs and pharmacists for making decisions about potentially interacting drugs or usual fatal error in prescribing. The systems varied markedly, due in part to the use of different knowledge bases but also to variable use of the same knowledge base but all traditional system used a regular expert system that not exactly match with the medical concepts and rule. In this study we mentioned the limitation of usual expert system for prescription and drug interaction checking. We proposed the architecture and fundamental of fuzzy expert system for improving the performance of prescription.

Key words: Fuzzy expert system, pharmacy information system, hospital information system

INTRODUCTION

Difficulties can arise at any part of the prescription process from the moment the prescriber makes the choice of drug treatment to the time the patient receives that treatment. However, they are defined, medication errors are very common and in many instances avoidable (Schrattenholz, 2004). Illegible prescriptions are one cause of avoidable medication error and electronic prescription systems are increasingly being introduced to remove this danger. Electronic prescribing systems can act as expert systems preventing other drug errors such as drug interactions (Roses, 2002).

They can also enforce local prescribing rules (Shortliffe, 1987). These systems have been shown to reduce drug errors. However, a well intended action can often have the unintended consequence of introducing unforeseen errors. The sheer number of warning messages generated by the system regarding potential interactions and laboratory results may overwhelm doctors. Not all of these warnings will be clinically important and doctors may unconsciously override a warning that indicates a potentially serious problem (Li, 2005).

The concurrent use of multiple drugs is often attended with drug-drug interactions which represent an important category of adverse reactions to drugs (Pugazhenthi and Rajagopalan, 2007). Since information on drug interactions is huge in volume, scattered around in the literature and still increasing, it is hardly possible to check potentially dangerous drug combinations completely by manual method, particularly when a patient is administered the multitude of drugs. As an aid for the medical practitioners, some computerized drug information systems provide the services of drug-drug interaction checking (Classen *et al*., 1991).

Adverse Drugs Reaction (ADR) and harmful effects of pharmaceutical excipients imply severe incidences, due to incompatibilities of the drug with the medical history. The rate of ADR appearance is extremely high in worldwide hospitals (Gert *et al*., 2004). Hence, it represents an important clinical issue. Some studies have shown an ADR incidence about 6.7% of serious cases and 0.32% of deaths (Chen *et al*., 2005) over the total cases attended in worldwide hospitals. In Iranian hospitals the ADR ratio is so high. An example of ADR consequences are according to the study carried out by the Shahid Beheshti University Hospital (Iran), admission in 80% of cases, with a medium bed stay of eight days, a cost of $847 m and an overall fatality of 0.15% (Ziaaddini and Ziaaddini, 2005). Most of these consequences can be avoided with a review of drug interaction and allergies with some of the excipients (Ahmadi and Hasani, 2003).

We have used the data from one electronic prescribing system in use in the renal unit at the Razavi Hospital in IRAN to test the following hypotheses:

- An intervention by an expert computer prescribing system improves the prescribers future prescribing and so doctors will learn over time to avoid errors
- More senior doctors are more likely to disregard warnings

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- Warning messages following a prescription are less common for more senior doctors and more common as the workload of the unit (measured by the number of patients) increases

WHY FUZZY LOGIC

The primary reason for the success of fuzzy logic in process engineering is the ability to model highly efficient non linear systems for which mathematical models are non existent or inefficient in traditional rule based approach knowledge is encoded in the form of antecedent consequent structure. When new data is encountered it is matched to the antecedent clauses of each rule and those rules where antecedent data match are exactly fired, establishing the consequent clauses in the past decade fuzzy logic has proved a wonderful tool for intelligent systems in medicine. In the medicine especially in the oriental medicine most medical concepts are fuzzy. The imprecise nature of medical concepts and their relationship require the use of fuzzy (Farshchi and Yaghoobi, 2010). It defines exact medical entities as fuzzy sets and provides a linguistic approach with an excellent approximation to text. In this study we would like to discuss fuzzy set theory and fuzzy logic for developing knowledge based systems in prescribing system. In order to show how fuzzy set theory and fuzzy logic are suitable for representing handling medical; concepts three questions must be answered (Radha and Rajagopalan, 2007).

- What is logic
- What is fuzziness
- And what meaning has the term fuzzy logic

Logic studies the notions(s) of consequence: It deals with propositions, set of propositions and the relation of Consequence among them. The task of formal logic is to represent all this by means of well-defined logical calculi admitting exact investigation. Various calculi differ in their definitions of sentences and notion(s) of consequence (propositional logic, predicate logic, modal propositional/predicate logic and many-valued propositional/predicate logic).

Often a logical calculus has two notions of consequence: Syntactical (based on a notion of proof) and semantically (based on notion of truth); then the natural questions of soundness (does probability imply truth?) and completeness (does truth imply probability?). Medical fuzziness is impreciseness: A fuzzy proposition may be true in some degree. The word crisp is used as meaning non-fuzzy. Standard examples of fuzzy propositions use linguistic variables such as age with possible values young, medium, old or similar. The sentence the patient is young is true in some degree, the lower the age the more the truth. Truth of a fuzzy proposition is a matter of degree. Fuzzy logic in medicine has two different meanings-wide and narrow. In particular, such key concepts in FLN (Fuzzy Logic Network) as a concept of a linguistic variable, canonical form, fuzzy if-then rule, fuzzy quantification, the extension principle, the compositional rule of inference and interpolative reasoning, is not addressed in traditional systems.

Based on Zadeh’s opinions (Green, 2009) on fuzzy logic, we may conclude two things: First, in the broad sense, every thing dealing with fuzziness may be called fuzzy logic. Second, in the narrow sense, formal calculi of many-valued logic to be the base of fuzzy logic. The imprecise nature of medical concepts and their relationships requires the use of fuzzy logic. It defines inexact medical entities as fuzzy sets and provides a linguistic approach with an excellent approximation to texts. Fuzzy logic offers reasoning methods capable of drawing approximate inferences. For example, in Oriental medicine, for a back pain that is not caused by a disease, acupuncture is often very efficient. Rules of oriental medicine include words like severe pain that are difficult to formalize and to measure. On the other hand, traditionally, mathematics uses crisp (well-defined) property P(x) i.e., properties that are either true or false.

Electronic prescribing system: The computerized system stores each prescription or administration as a separate record which is linked to a unique patient number. New users receive up to 2 h of introductory training on the use of the system. Each user on the system has a unique identifier number. Individual doctors grades are identified using this number but not the individual users identities. The system generates warnings using the rules designed into it and maintains a record of every occasion a message is displayed. Each message can be linked to the user whose action generated it, to the individual prescription (using a unique prescription key) and to the outcome of the warning-that is, whether the prescription was abandoned or followed through. If the message is disregarded the doctor is making the decision to note the content of the message, to disregard any warning and to go ahead and prescribe. Otherwise, the prescription process stops and the drug is not prescribed. The severity of the messages is graded as follows:

- Information-no action required
- Red information-no action required
- Warning-must be ticked off before prescription can be completed

- PopUp information-must press OK (no alternative)
- Password-must be ticked off and password entered before prescription can be completed
- System-where the drug dosage or interactions were not held by the computer system
- Disallow-cannot be disregarded

Some procedures will generate multiple messages and some of these will be unavoidable. For example, when changing the dose of vancomycin from 1 g to 500 mg, if the number is changed first a message will be generated because gram is the default unit of vancomycin. Also some are nurse messages-that is, standard messages for a particular form of a drug which are displayed to the nurse administering the drug but can also be viewed by pressing a button on the screen (in other words, you do not have to be prescribing or administering a drug to see these messages).

Some messages will appear in certain circumstances-for example, There are no daily dose limits defined, or There are no single dose limits defined, or which start with There are no dose limits defined, Total of doses must be, or First administration due. We did not consider further those messages that were solely informational rather than warning.

Fuzzy prescribing system: Fuzzy logic systems have the structure of a series of if-then rules for modeling. For example, if the drug dosage is moderate then the response should be good. In traditional systems these rules are structured as decision trees based on bivalent logic (i.e., the dose is either moderate or not and the response is either good or not) (Campbell and Cueva, 1995). In fuzzy system modeling, fuzzy sets are used in the rules to form the knowledge base. For example, if the dosage is mostly moderate then the response should be good to a certain degree. The underlying mathematics of a fuzzy system is not fuzzy (Green, 2009). The fuzzy rules are mathematical relationships mapping inputs to outputs. Each step of the process is continually under investigation for improvements or for customization for particular situations. One of the most widely known fuzzy logic modeling algorithms is that of Sugeno-Yasukawa (Haas *et al*., 2007; Amiri *et al*., 2009). There have been many successful applications of fuzzy systems, particularly with consumer goods (Farshchi, 2010a). For example, washing machines have been developed using a fuzzy control system where the wash cycle changes strategies as the clothes become clean. Other examples include fuzzy controlled vacuum cleaners and subway trains, in addition to unmanned helicopter control and navigation. Although not the focus of this review, a neural network is a system of processing elements (nodes) and weighted connections that is able to learn to recognize patterns in data to solve a computational problem. Neural networks have been applied to pharmacokinetic and pharmacodynamic systems and can be used in conjunction with fuzzy logic, for example, as a method for developing the fuzzy rules.

Our fuzzy expert system modeling can be pursued using the following steps.

- Select relevant input and output variables. Determine the number of linguistic terms associated with each input/output variable (can called from EHR). Also, choose the appropriate family of membership functions, fuzzy operators, reasoning mechanism and so on
- Choose a specific type of fuzzy inference system (for example, Mamdani, Takagi-Sugeno etc.). In most cases, the inference of the fuzzy rules is carried out using the min and max operators for fuzzy intersection and union
- Design a collection of fuzzy if-then rules (knowledge base). To formulate the initial rule base, the input space is divided into multidimensional partitions and then actions are assigned to each of the partitions

RESULTS AND DISCUSSION

Evaluating the use of fuzzy sets and fuzzy logic in pharmacology and prescribing has barely begun. To date, such evaluation has been used primarily to model the actions of drugs and thereby control the delivery of drugs that are infused, exhibit rapid and directly measurable pharmacological effects and have short durations of action.

Doctors who were experienced in the use of some fuzzy system and who finished working on the unit in July were much less likely to generate a warning message than the six doctors who were new to the system in August (Noury *et al*., 2008). However, the new doctors rapidly improved their prescribing, as judged by the number of warning messages per prescription. This may have been in part because the pre-registration house officers who started in August were new to prescribing and their prescribing behavior improved generally over the 3 week period, as well as because they were learning to use the system. There was an association between the grade of doctor and the number of warning messages generated. Junior doctors were less likely to disregard these warning messages (and proceed with the prescription) than more senior doctors. For example, warnings of doxazosin: Interactions with calcium channel blockers and warfa rin interacts with omeprazole were often ignored by consultants. Since doxazosin was prescribed for refractory hypertension and since blood clotting was regularly monitored in patients on warfarin, the theoretical dangers were largely removed in the context of the renal unit. The system used in that study had some expertise-for example, in displaying the results of recent relevant investigations such as blood urea concentration, or in warning of some drug interactions (Farshchi, 2010b). The number of non-intercepted preventable adverse drug events had been found that actually occurred fell by 17% when physician order entry was computerized but the number of potential adverse drug events fell by 84% over 9 months. Clearly, fuzzy expert systems mitigate or eliminate errors due to handwriting in the same way as less sophisticated systems, but they also have additional benefits. We were surprised how rapidly prescribing changed. After 3 weeks of using the expert system the number of warning messages fell by half. We did not examine the number of non-intercepted medication errors that continued to occur but we looked at the way in which the prescribing behavior of doctors was modified by interaction with an expert computerized prescribing system. Since the computer generates warning messages when errors are made in prescribing, a reduction in the number of warning messages equates to improve-that is, safe-prescribing. We do not know whether improved prescribing behavior persists when doctors move to areas where there is no computerized prescribing. This is a potentially important question to answer. If behavior is modified in the medium or long term, then there is hope that expert systems will be able to train prescribers to adopt safer patterns of work. Thus, expert prescribing systems may have beneficial effects far beyond the areas in which they are used. By contrast, systems which replace a handwritten prescription with a computer printed one are unlikely to have any educational benefit.

We conclude that clinical staff adapts rapidly to computer prescribing and that their prescribing behavior is modified to reduce the number of warning messages of serious danger displayed by the system. Provided the rules governing warning messages are carefully constructed, the alignment of doctors prescribing practice with the rules should improve patient safety. It remains to be seen whether the benefits of exposure to such computerized systems are maintained after prescribers cease to use them.

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