International Journal of Engineering Research & Technology (IJERT)
NCRTS`14 Conference Proceedings
ISSN: 2278-0181

A Review on Clinical Decision Support System and Its Scope in Medical Field

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***Abstract*—This paper gives an introduction to a system or tool called as clinical decision support system (CDSS). A CDSS is basically any computer program which is designed to help health professionals make clinical decisions; clinical decision may be diagnosis of a disease, advices and reminders to patients etc. The work of healthcare professionals and physicians is largely a work of making decisions and solving problems. It is a work of choosing issues that require attention, setting goals, finding or designing suitable courses of action and evaluating and choosing among alternative actions. They must choose from and interpret a huge variety of clinical data, while facing pressure to decrease uncertainty, risks to patients and costs. The true essence of healthcare delivery is decision making - what information to gather, which tests to order, how to interpret and integrate this information into diagnostic hypotheses and what treatments to administer.**

Despite great steps forward, however, uncertainty still plays a pivotal role in most aspects of medical decision making. Doctors may know that a patient does not have long to live, but they cannot be certain how long. Similarly, they may prescribe a potent new receptor blocker to reverse the course of a patient's illness, but they cannot be certain that the therapy will do so without side effects. This uncertainty is compounded by the information overload that characterises modern medicine. Today's experienced clinician needs close to 2 million pieces of information to practice medicine and doctors subscribe to an average of seven journals, representing over 2,500 new articles each year, making it almost impossible to keep abreast with the latest information about diagnosis, prognosis, therapy and related health issues. Furthermore, the interpretation of patient data is difficult and complicated, mainly because the required expert knowledge in each of many different medical fields is enormous and the information available for the individual patient is multi- disciplinary, imprecise and very often incomplete.

This has prompted the need to make use of CDSS to provide means for clinicians to receive the relevant research-supported evidence necessary for safe, effective and efficient clinical decision making. Clinical decision support system offers the obvious solution both for the management of information and for its faster retrieval.

Keywords*—*clinical decision support system, diagnosis, advice, reminders, information management, knowledge base, Bayesian Network, Neural Network, Rule-Based System.

I. INTRODUCTION

Clinical decision support systems (CDSS) are computer systems designed to impact clinician decision making about individual patients at the point in time that these decisions are made. With the increased focus on the prevention of medical errors, CDSS have been proposed as a key element of systems' approaches to improving patient safety. If used properly, CDSS have the potential to change the way medicine has been taught and practiced.

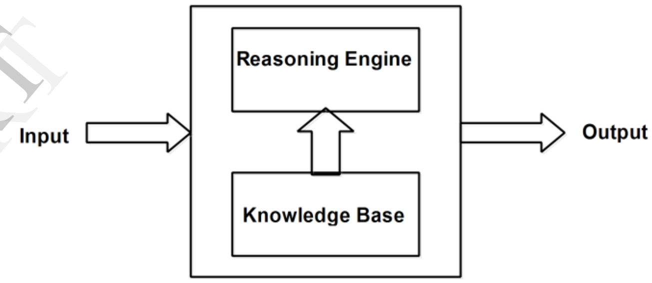

Fig 1: A general model of a clinical diagnostic decision support system

There are a variety of systems that can potentially support clinical decisions. Even Medline and similar healthcare literature databases can support clinical decisions. Decision support systems have been incorporated in health- care information systems for a long time, but these systems usually have supported retrospective analyses of financial and administrative data. Recently, sophisticated data mining approaches have been proposed for similar retrospective analyses of both administrative and clinical data. Although these retrospective approaches can be used to develop guidelines, critical pathways, or protocols to guide decision making at the point of care, such retrospective analyses are not usually considered to be CDSS. These distinctions are important because vendors often will advertise that their product includes decision support capabilities, but that may refer to the retrospective type of systems, not those designed to assist clinicians at the point of care.

Although CDSS have been developed over the last thirty years, many of them have been stand-alone systems or part of non-commercial computer based patient record systems. CDSS also differ in whether the information provided is general or specialty-based. In recent years, some of the originally non-commercial systems are now being more widely marketed, and other vendors are beginning to incorporate CDSS into their computer based patient records and physician order entry systems. Another categorization scheme for CDSS is whether they are knowledge-based systems, or non-knowledge based systems that employ machine learning and other statistical pattern recognition approaches.

II. BASIC CONCEPTS

A. *Knowledge-Based Clinical Decision Support Systems*

Many of today's knowledge-based CDSS arose out of earlier expert systems research, where the aim was to build a computer program that could simulate human thinking. Medicine was considered a good domain in which these concepts could be applied. In the last twenty years, the developers of these systems have begun to adapt them so that they could be used more easily to support real-life patient care processes. Many of the earliest systems were diagnostic decision support systems. The intent of these CDSS was no longer to simulate an expert's decision making, but to assist the clinician in his or her own decision making. The system was expected to provide information for the user, rather than to come up with "the answer," as was the goal of earlier expert systems. The user was expected to filter that information and to discard erroneous or useless information. The user was expected to be active and to interact with the system, rather than just be a passive recipient of the output. This focus on the interaction of the user with the system is important in setting appropriate expectations for the way the system will be used.

B. *Non-knowledge-Based Clinical Decision Support Systems*

Unlike knowledge-based decision support systems, some of the non-knowledge-based CDSS use a form of artificial intelligence called machine learning, which allows the computer to learn from past experiences and/or to recognize patterns in the clinical data. Artificial neural networks and genetic algorithms are two types of non-knowledge-based systems.

Artificial neural networks or more generally neural networks use nodes and weighted connections between them to analyze the patterns found in the patient data to derive the associations between the symptoms and a diagnosis. This eliminates the need for writing rules and for expert input. However since the system cannot explain the reason it uses the data the way it does, most clinicians don't use them for reliability and accountability reasons.

Genetic Algorithms are based on simplified evolutionary processes using directed selection to achieve optimal CDSS results. The selection algorithms evaluate components of random sets of solutions to a problem. The solutions that come out on top are then recombined and mutated and run through the process again. This happens over and over until the proper solution is discovered. They are the same as neural networks in that they derive their knowledge from patient data. Non-knowledge-based networks often focus on a narrow list of symptoms like ones for a single disease as opposed to the knowledge based approach which cover many different diseases to diagnosis.

III. DETAILED DESCRIPTION

A. *Knowledge-Based Clinical Decision Support Systems*

There are three parts to most CDSS. These parts are the knowledge base, the inference or reasoning engine, and a mechanism to communicate with the user. The knowledge base consists of compiled information that is often, but not always, in the form of if–then rules. An example of an if–then rule might be, for instance, IF a new order is placed for a particular blood test that tends to change very slowly, AND IF that blood test was ordered within the previous 48 hours, THEN alert the physician. In this case, the rule is designed to prevent duplicate test ordering. Other types of knowledge bases might include probabilistic associations of signs and symptoms with diagnoses, or known drug–drug or drug–food interactions.

The second part of the CDSS is called the inference engine or reasoning mechanism, which contains the formulas for combining the rules or associations in the knowledge base with actual patient data.

Finally, there has to be a communication mechanism, a way of getting the patient data into the system and getting the output of the system to the user who will make the actual decision. In some stand-alone systems, the patient data need to be entered directly by the user. In most of the CDSS incorporated into electronic medical records (EMR) systems, the data are already in electronic form and come from the computer-based patient record, where they were originally entered by the clinician, or may have come from laboratory, pharmacy, or other systems. Output to the clinician may come in the form of a recommendation or alert at the time of order entry, or, if the alert was triggered after the initial order was entered, systems of email and wireless notification have been employed.

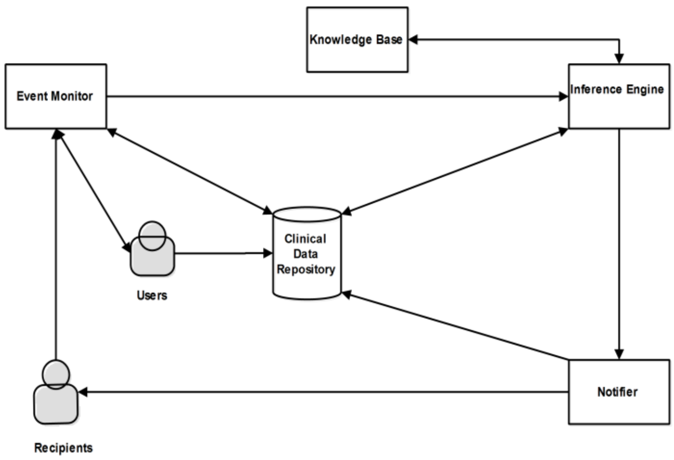

Fig.2: Knowledge-based clinical decision support system

CDSS have been developed to assist with a variety of decisions. Diagnostic decision support systems have been developed to provide a suggested list of potential diagnoses to the users. The system might start with the patient's signs and symptoms, entered either by the clinician directly or imported from the EMR. The decision support system's knowledge base contains information about diseases and their signs and symptoms. The inference engine maps the patient signs and symptoms to those diseases and might suggest some diagnoses for the clinicians to consider. These systems generally do not generate only a single diagnosis, but usually generate a set of diagnoses based on the available information. Because the clinician often knows more about the patient than can be put into the computer, the clinician will be able to eliminate some of the choices. Most of the diagnostic systems have been stand-alone systems, but there are few which take data which are in EMR.

Other systems can provide support for medication orders, a major cause of medical errors. The input for the system might be the patient's laboratory test results for the blood level of a prescribed medication. The knowledge base might contain values for therapeutic and toxic blood concentrations of the medication and rules on what to do when a toxic level of the medication is reached. If the medication level was too high, the output might be an alert to the physician. There are CDSS that are part of computerized physician order entry (CPOE) systems that take a new medication order and the patient's current medications as input, the knowledge base might include a drug database and the output would be an alert about drug interactions so that the physician could change the order. Similarly, input might be a physician's therapy plan, where the knowledge base would contain local protocols or nationally accepted treatment guidelines, and the output might be a critique of the plan compared to the guidelines. Some hospitals that have implemented these systems allow the user to override the critique or suggestions, but often the users are required to justify why they are overriding it. The structure of the CDSS knowledge base will differ depending on the source of the data and the uses to which they are put. The design considerations, especially vocabulary issues, are not trivial.

B. Non-knowledge-Based Clinical Decision Support Systems

CDSS's that do not use a knowledge base use a form of artificial intelligence called machine learning, which allow computers to learn from past experiences and/or find patterns in clinical data. Two types of non-knowledge-based systems are artificial neural networks and genetic algorithms

1) Artificial neural networks

Research in neural networks has been going on since the 1940s. Artificial neural networks (ANN) simulate human thinking and learn from examples. An ANN consists of nodes called neurodes (which correspond to neurons) and weighted connections (which correspond to nerve synapses) that transmit signals between the neurodes in a unidirectional manner. An ANN contains 3 layers, which include the input layer, output layer, and hidden layer. The input layer is the data receiver and the output layer communicates the results, while the hidden layer processes the incoming data and determines the results.

This structure bears some similarities to the knowledge-based decision support systems, but rather than having a knowledge base derived from the medical literature or from an expert clinician's knowledge, the ANN analyzes the patterns in the patient data, to derive the associations between the patient's signs and symptoms and a diagnosis. Many of the knowledge- based CDSS cover a wide range of diseases. For instance, the input may be the signs and symptoms exhibited by a patient and the output may be the possible diseases the patient may have. Neural networks often focus on a more narrow range of signs and symptoms, for instance, those associated with a single disease, such as myocardial infarction.

These systems can learn from examples when supplied with known results for a large amount of data. The system will study this information, make guesses for the correct output, compare the guesses to the given results, find patterns that match the input to the correct output, and adjust the weights of the connections between the neurodes accordingly, in order, to produce the correct results. This iterative process is known as training the artificial network. In the example with myocardial infarction, for instance, the data including a variety of signs and symptoms from large numbers of patients who are known to either have or not have a myocardial infarction can be used to train the neural network. Once the network is trained, i.e., once the weighted associations of signs and symptoms with the diagnosis are determined, the system can be used on new cases to determine if the patient has a myocardial infarction.

There are many advantages and disadvantages to using artificial neural networks. Advantages include eliminating the need to program IF–THEN rules and eliminating the need for direct input from experts. ANNs can also process incomplete data by inferring what the data should be and can improve every time they are used because of their dynamic nature. ANNs also do not require a large database to make predictions about outcomes, but the more comprehensive the training data set is, the more accurate the ANN is likely to be. Even though all of these advantages exist, there are some disadvantages. The training process involved can be time consuming.

ANNs follow a statistical pattern recognition approach to derive their formulas for weighting and combining data. The resulting formulas and weights are often not easily interpretable, and the system cannot explain or justify why it uses certain data the way it does, which can make the reliability and accountability of these systems a concern.

Despite the above concerns, artificial neural networks have many applications in the medical field. Study results have shown that ANNs' diagnostic predictions for pulmonary embolisms were as good as, or better than, physicians' predictions [8]. Another study also showed that neural networks did a better job than two experienced cardiologists in detecting acute myocardial infarction in electrocardiograms with concomitant left bundle branch block [9]. Studies have also shown that ANNs can predict which patients are at high risk for cancers such as oral cancer [10].

2) Genetic Algorithms

Another non-knowledge based method used to create CDSS is a genetic algorithm (GA). GAs were developed in the 1940s by John Holland at the Massachusetts Institute of Technology, and are based on the evolutionary theories by Darwin that dealt with natural selection and survival of the fittest[11]. Just as species change to adapt to their environment, "GAs 'reproduce' themselves in various recombinations in an effort to find a new recombinant that is better adapted than its predecessors.

In other words, without any domain specific knowledge, components of random sets of solutions to a problem are evaluated, the best ones are kept and are then recombined and mutated to form the next set of possible solutions to be evaluated, and this continues until the proper solution is discovered. The fitness function is used to determine which solutions are good and which ones should be eliminated. GAs is similar to neural networks in that they derive their knowledge from patient data.

Genetic algorithms have also been applied in health care, but there are fewer examples of this type of CDSS than those based on neural networks. However, GAs has proved to be a helpful aid in the diagnosis of female urinary incontinence.

Although research has shown that CDSS based on pattern recognition and machine learning approaches may be more accurate than the average clinician in diagnosing the targeted diseases, many physicians are hesitant to use these CDSS in their practice because the reasoning behind them is not transparent. Most of the systems that are available today involve knowledge-based systems with rules, guidelines, or other compiled knowledge derived from the medical literature. The research on the effectiveness of CDSS has come largely from a few institutions where these systems were developed.

IV. CONCLUSION

There is now growing interest in the use of CDSS. More vendors of information systems are incorporating them. As scepticism about the usefulness of computers for clinical practice decreases, the wariness about accepting the CDSS' advice, that many clinicians currently exhibit, is likely to decrease. As research has shown, if CDSS are available and convenient, and if they provide what appears to be good information, they are likely to be heeded by clinicians. Ultimately, the essence of this paper is the perspective that as CDSS becomes widespread, we must continue to remember that the role of the computer should be to enhance and support the human who is ultimately responsible for the clinical decisions.

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