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A Rule based Clinical Decision Support System for Healthcare Industry

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Abstract

Objectives: The main aim of this work is to enhance the quality of medical care by reducing the turnaround time of reminder and maintenance. This work intends to propose suitable Decision Support System (DSS) for medical industry. **Methods**: DSS can interpret information and create a supporting system for decision making. In medical industry, DSS is highly important since the disease, symptoms of the disease and relevant treatment methods are not predictable. This study proposes a DSS for helping medical experts in a ubiquitous medical system which can use the DSS. **Findings**: Here we proposed a web-based editor to create a rule which can be understood and can be modified by the clinicians. The proposed DSS can support the healthcare experts by rule-set method and expert system. To improve the quality of care in a medical industry, a clinical reminder to get alert automatically from the clinical documents is of much use. From the evidence of the document, a Novel Rule set is created. The new rule can be inferred and it can be implemented after the approval of clinicians. It is based on the previous rules and histories have to infer new rules to apply.

Keywords: Clinical Information System, Decision Making, Decision Support System, Knowledge Extraction

1. Introduction

Data mining is one of the growing research industries used in various applications. Some of the big data, especially medical industry data has more objectives, different structure and more conflicts. Due to the conflicts, the data analysis is difficult in medical/healthcare dataset. Data mining accuracy is better in any kind of big data if the quality of the data is improved. To improve the quality of the data, preprocessing, data cleaning by error elimination, redundancy removal and store it in a standard format are some of the sequences of data-processing methods applied on the data. Almost, all of the IT companies need data processing and data mining process efficiently. One of the main tasks in data mining in decision making where it selects a particular constraint-based data using logical relationship. A human can take best choice of decision for a specific condition based on the user requirement or certain constraints for efficient decision making. In other words, decision making helps the managing people in a company to solve problems by verifying the choices and decide a better route.

Decision making highly provides a positive impact on selecting the results. One of the main process supports decision making process is Decision Support System (DSS), is a human computer interactive model which helps the user to judge about their choice of result generation. DSS provides an enhanced information retrieval

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system in various data models. Some of the popular areas where DSS is used are healthcare, military and various businesses. Any application using DSS can manage and hit the decision at any kind of situation in their business process. One of the most famous DSS applications is a Clinical Decision Support System where it is used to analyse the data for helping healthcare industry to create some clinical decisions. Clinical Decision Support System (CDSS) is a continuous, circumstantial and embryonic process and it gather, interpret and evaluate the data to choose a better choice.

In order to maintain and improve the healthcare quality and cost of the data management, it is very much important to find out innovations in various aspects continuously. Innovations can be obtained in any of the aspects like new idea, method, concept, processes, instrument, diagnosing method, services and treatment methodologies[1]. Each medical industry has a minimum of six service departments like diagnosing, treating, preventing, educating and research on patients and the diseases. While serving the above said processes, the medical industry needs to maintain the quality in management, costs, security, efficacy and outcomes. Innovations in healthcare industry mainly focused on the three core areas like, how caring the patient, how the patient's requirements are fulfilled.

2. Background Study

Earlier CDSS were created using expert systems where it has been developed using logical rules where make the model to think like a clinical expert challenged with a patient. CDSS in the earlier days are considered as knowledge based DSS, since it includes pre-compiled clinical knowledge. In[2] stated that the earlier research work was increasing rapidly as a recognition system used various applications including clinical industry. It has been used for deciding about a task different from routine tasks where it provides accurate suggestions regarding clinician's query. A detailed review was presented in[3] stating that CDS was considered as knowledge based CDS because it includes prior knowledge about clinical systems. In[4] has presented an elaborated taxonomy of Clinical Decision Support System and their functionalities. In[5] various existing CDS methods provide clinical expert consultation for diagnosing the medical data. But in recent days CDSS is improved by the efficiency regarding suggestions provided on the data and query.

3. Problem Statement

For the medical practitioners, the Clinical Decision Support Systems (CDSSs) provides best support to make decisions with good knowledge gaining and making foremost role to play in the support systems. There are limitations in the enhancement of these support systems to make convenient for the medical practitioners. First limitation is that incorporating the CDSSs in to hospital management systems and their database – requires more time and work for the medical practitioners. They have to make and maintain the data bases and also sharing and reusing the validated knowledge bases are the most difficult job to them because of their eccentricity and lack of intelligibility for users outside the originating organization. And also, it is hard for them to maintain and update the CDSSs on the daily basis.

A massive amount of data is generated every single day by the health care industry solitarily. In order to capture and transfer information, we use Information Technology (IT)[6]. The ultimate goal of the healthcare industry is to provide better and effective services for enabling the protection of mental and physical health of human and animals. For automating processes like transaction, inventory keeping and maintaining records which in turn eliminates mundane and repetitive processes is done with the help of IT[7] and therefore making healthcare industry grow faster. Physicians and other healthcare professionals are assisted by a well-defined decision support system to do clinical decisions. Any medical DSS is used to manage, persist and explode the huge amount of medical data. This system avoids errors due to physicians' insufficient knowledge which in turn improves the data management, searching and retrieving accurate medical information to do accurate disease diagnosis and appropriate treatment.

Using medical DSS enables, fast and specific diagnosis, more efficient drug prescriptions processing and reduces the need for specialist consultations, thus decreasing healthcare cost[8,9]. The medical diagnosis of an illness can be done oral investigation with the patient, manual tests and laboratory tests. The MDSS impact on the quality of care must be monitored continuously and its outcome must be studied carefully. Also, in cases, where the user overrides the system's advice, the MDSS should provide a method to capture such anomalies.

4. Healthcare Engineering

Innovation in healthcare industry leads by utilizing system-engineering tools. The tools of Engineering - Information Technology are being used widely in various applications to attain major improvements in the efficiency, quality, safety or process where customer is the most prioritised. Though the healthcare has shown valuable returns to the increasing number of healthcare organisations, they have been very slow to embrace the above-mentioned tools.

In higher levels of healthcare system, healthcare engineering tools are used to measure, characterize and optimize performance. The various healthcare systems for e.g. are:

- Individual healthcare organisations,
- Regional care system,
- Public healthcare system, etc.

Some of the healthcare engineering tools are discussed below.

5. Healthcare Support System

Medical DSS are attaining more popularity in different fields of medical/healthcare industries. All these are individually valuable based on the situations where the patient and medical information are prohibitive. Each medical data or information can provide a better decision or suggestions for future actions which helps to treat other patients. Other than the people related to medical industry, none of them should access the medical data. DSS in medical industry helps the human cognitive insufficiencies by incorporating different sources of health information, provides intellectual access to appropriate healthcare knowledge and assisting the process of organising the medical decisions.

The medical support systems can be built from any one of the formal approaches like decision theory, operation research and statistics. Artificial Intelligence methods can also be included in the DSS. If the problem is more complicated or big data based then DSS can be derived from heuristic or metaheuristic methods to obtain optimal decisions. During the decision-making time, various constraints and checkpoints need to be fulfilled to provide better decision on diagnostic and treatment. The medical information provides more general, clinical knowledge, guidance and intellectual information with the relevant supporting information. Some of the components used in Medical Decision Support System are:

6. Data Mining

The amount of data generated in healthcare/medical industry is increasing day by day. The structure of the data comes from various sources which are different in nature and structure, managing all the data in a single point is highly complex. The data is about patient, diseases, diagnosing report, history of treatment applied to the patient, hospital history, medical devices used and various resources. Medical industry always needs the prior knowledge about the patient and treatment applied for the particular patient to precede further treatment and care. Hence it is essential to extract the relevant knowledge from the existing medical information to support further processes in medical industry. This helps to save time, improve the accuracy in treatment and reduce the cost. It helps to provide a better decision support system in medical industry. In order to extract the relevant, data mining tools are applied. The data mining tools and methods can extract the visible and hidden information

about the data to help the medical professionals in getting additional information for decision making. The knowledge extraction can able to help medical diagnosis.

7. Decision Support System in Healthcare

DSS is used in healthcare industry in two different ways such as lower level processes and higher-level processes. Patient management, disease diagnosis, appropriate treatment applying, record maintenance, finance management and inventory management are the lower-level processes in healthcare industry. Decision making, doctor allocation and medicine suggestions are the higher-level processes. DSS in healthcare industry provides a knowledge dictionary having the information about diseases, symptoms, diagnosed reports and treatment applied with success and bad stories. It provides to which disease what kind of assistance can be provided, patient condition at each stage of the treatment, drug applied, dosage limit and time of drug usage.

7.1 Expert System

Expert system comprises of various applications for various domains. It can be selected according to the situations where the exert is not currently available. An expert system can be designed by extracting knowledge from the corresponding domain experts. Then it will be converted into a computer program, implemented and executed for the core data. Knowledge is extracted from the domain experts by the engineer to perform a task using any expert system like rule-based expert system which basically uses the knowledge. Figures 1 and 2 illustrate the various modules of the rule-based system. Expert system can be developed and used in many fields. Knowledge is a kind of problem understanding theoretically and practically about the corresponding domain or the subject.

Knowledge is the entire known contents about any domain. Medical diagnosis system is one of the systems which find out the diseases and symptoms using a device, manual check-up or by giving any drug inside the human body. Online knowledge-based system is developed for

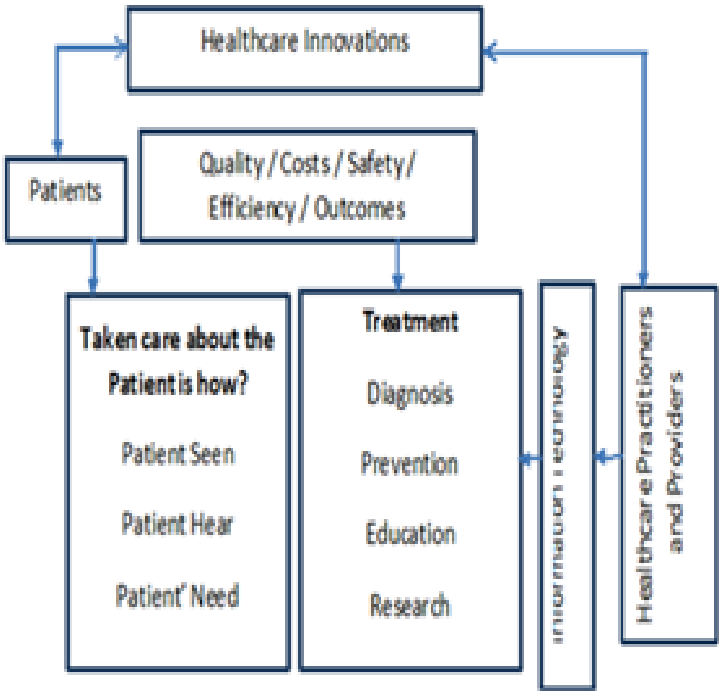

Figure 1. A conceptual framework for innovation in healthcare.

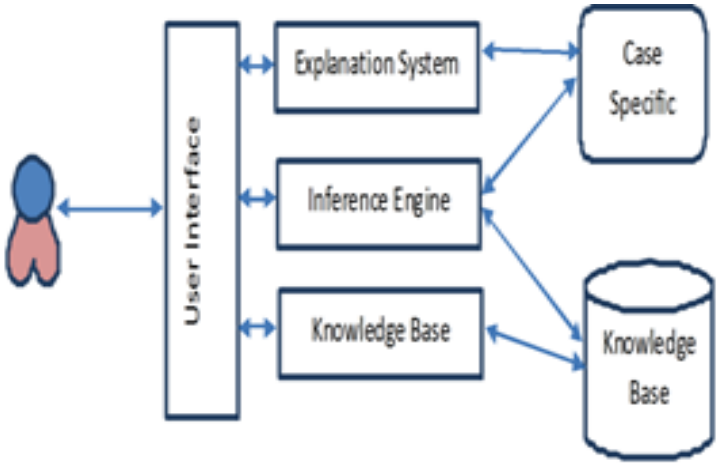

Figure 2. Components of expert system.

diagnosing the diseases in accordance to the knowledge given by medical experts in the system. All the medical professionals like medical students, research scholars, pharmacists, doctors keep their knowledge up-to-date to create a knowledge database where it has been updated regularly.

7.2 DSS Design

The entire functionality of the medical DSS is illustrated in Figure 3. It explains how the DSS functions in a medical industry. Patient complaints are initially recorded and learn the patient condition by interviewing the patient

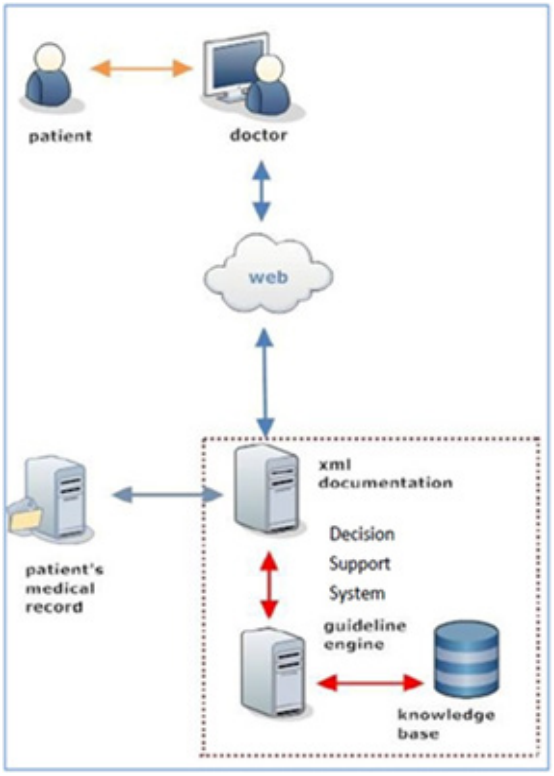

Figure 3. Medical Decision Support System.

by manual interaction. It is well known that the patient comes to doctor because of a disease. So, the doctor interviews the patient in order to understand thoroughly about the patient and the disease. It helps the doctor to find out the possible disease and the stage of the disease as mild, moderate or severe. After confirming the disease, the doctor prepares a description about the disease, medicine, dosage limit and the appropriate time.

7.3 Proposed System

In this paper, the objective is to design and develop a Medical Decision Support System for assisting medical professionals in diagnosing their diseases. While diagnosing, the DSS extracts the relevant information from knowledge-based database created already to improve the accuracy of the diagnosing results. One of the major aims of developing a DSS is to provide a relevant data or information to the user for assisting in preparing diagnosis report.

The medical DSS connects the patient and the doctor/medical experts to treat the patient based on their clinical condition and ensure the standard patient condition/information and it will be exchanged among various health institutions. In this paper a DSS based service is provided for chronic diseases by referring the physicians' rule set.

To understand the patient's or the medical expert's role, Table 1 gives detailed information. One of the main advantages is, the medical DSS can be customized according to the health condition of the patient through the inference engine. The output of the knowledge base is a conclusion message using a pattern matching method or a solution finder. Searching is obtained by integrating the pattern with attribute of the patient data. The pattern matching match the value of the variables and rule set through inference engine. The final message is created according to the health condition of the patient. The output message can also personalise through the interface. Figure 4 illustrates the entire functionality of the medical DSS where it provides an output message for the patient, which can be easily understand. Each time the Body Mass Index is compared with the knowledge base and the DSS provides a suggestion. It is very fast and efficient. The present patient BMI value is recorded and use the pat-

Figure 4. Rule based Medical Decision Support System.

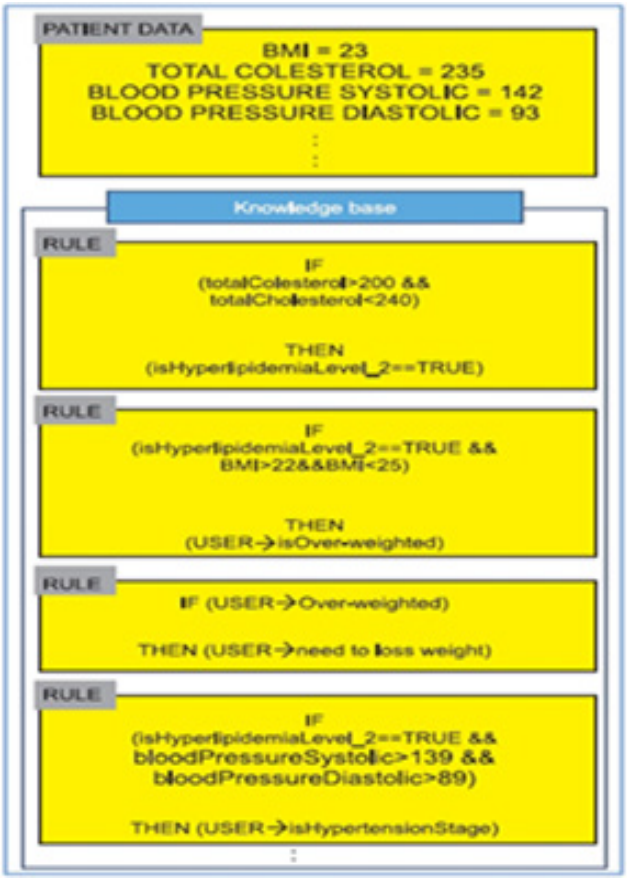

Figure 5. Rule based system.

tern matcher and solution finder in order to obtain the decision.

Figure 5 illustrates the increased inference using attribute values of the blood level, cholesterol level and

Table 1. Role of the patient and physician

Role involved in HDSS	Rule creation and evolution	Self-management
Patient	Existing can be developed by receiving feed-back data from patient	Lifestyle information and health screening schedule service are provide timely for self management of chronic
Physician	Rules are create to provide customized guide lines to patient with chronic disease on the basis of medical knowledge such as new scientific findings and clinical study results	Patients can perform self management eases through the rules provided by physicians the rules are evolved through patient feedback

systolic-diastolic blood pressures. The rule-based inference system uses attributes (which is new facts) of the objects and compare with a predefined threshold values which could helps to obtain a decision.

8. Experimental Results and Discussion

To experiment and verify the efficiency of the proposed medical DSS, more than 9000 patient's electronic records are collected and input into the DSS. According to the rule-based system the entire data is experimented and the decision results are verified. To reduce the execution time and computational complexity the experiment is carried out into five numbers of times with different size of data and it is given in Table 2. Each set of data is considered as different dataset and decision making applied. From the entire dataset, initially based on the Body Mass Index (BMI) value the normal, disease and various symptoms-based records are classified and it is given in Table 2. It illustrates the classification applied by comparing the general BMI values. For example, BMI value is from 20 to 25 and then the patient health condition is normal. If the BMI value is lesser than 18.5, then it indicates the patient

Table 2. Data classification based on the BMI general value

Data in DB	Normal Data (%)	Disease (%)	Symptoms (%)
Dataset-1 (1000-Numbers)	45%	42%	13%
Dataset-2 (2000-Numbers)	33%	40%	27%
Dataset-3 (2000-Numbers)	36%	29%	35%
Dataset-4 (2000-Numbers)	23%	43%	28%
Dataset-5 (2000-Numbers)	39%	51%	10%

Table 3. Disease classification

Gender	Age	Cancer	TB	Viral Infection
Male	15-25	4%	23%	14%
	25-35	17%	36%	17%
	35-50	46%	26%	18%
	>60	53%	19%	21%
Female	15-25	6%	35%	28%
	25-35	19%	43%	27%
	35-50	36%	29%	33%
	>60	43%	27%	38%

Table 4. Performance analysis

Data set		Data base		Proposed DSS	
	Total	**Normal**	**Abnormal**	**Normal**	**Abnormal**
Dataset-1	4500	2800	1700	2797	1695
Dataset-2	4500	3400	1100	3398	1098
Total	9000	6200	2800	6195	2793

condition is less than normal and dissevers. Comparing with the classification, the average classification says that, the number of patients affected by various diseases is little high than the normal. A moderate number of patient's health condition shows the symptoms through their record. In certain cases, symptoms may be available but cannot decide about the diseases. In some other case, it is very easy to judge about the disease but cannot find out any related symptoms. Hence the DSS requires deciding about the health condition of the patient based on the diseases, symptoms and combining both. Decision making in terms of diseases using medical DSS is given in Table 3. It classifieds the gender, age and the number of patients affected by cancer, TB and viral infection. The number of patient's age group from 35 to 50 and above 60 has been affected by various diseases than the younger age group patients.

The performance of the proposed DSS is evaluated by comparing the classified results and the existing results in the database. The compared result is given in Table 4. From the table it is clear and noticed that the proposed DSS is better in decision making in medical industry. To evaluate the performance, some of the performance metrics are calculated in the experiment. True Positive, False Positive, True Negative and False Negative are some of the metrics used for performance comparison.

- True positive is correctly identifying the malicious users as malicious users.
- False positive is incorrectly identifying the normal user as malicious user.
- True negative is correctly identifying normal user as the normal user.
- False negative is incorrectly identifying the abnormal user as normal user.

From the Table 4, the calculated TP, TN, FP and FN are:

TP = 2793

TN =6195

FP = 5

FN =7

From the performance metrics

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = \frac{2793+6195}{2793+6195+5+7} = \frac{8988}{9000} = 0.9986 = 99.86\%.$$

From the accuracy it is decided that the proposed medical DSS can support any medical industry or healthcare system in real time.

9. Conclusion

This study motivated and implemented a Medical Decision Support System which incorporates manual interaction with the patient, domain knowledge creation and comparison, knowledge extraction and rule-based knowledge system. This approach provides a better decision-making assistance to the medical experts at the right time in online as well as in offline to take care of the patients. From the experimental results, it is concluded that the proposed medical DSS provides better service in terms classification accuracy and proved.

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