

Clinical Decision Support Systems: A discussion on different methodologies used in Health Care

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Abstract—Today computer science has revolutionized our world and computers have become vital component of our life. It made it easy for us to analyze and diagnose the medical problems and diseases. The use of Artificial Intelligence in medicine and medical sciences are on high demand. This paper focuses on the characteristics of Clinical Decision Support System and the methodologies used for their implementation. It discusses how they are helpful in diagnosis of diseases and pain. The purpose of this case study is to study the aspects of Clinical Decision Support Systems and to figure out the most optimal methodology that can be used in Clinical Decision Support Systems to provide the best solutions and diagnosis to medical problems. The case study includes the reading and understanding of the previous research works and to find out better methodologies. The paper concludes that every methodology has some good aspects as well as some dark aspects. The selection of a particular methodology depends upon various parameters of problem domain. Certain methodologies are more effective in one domain while other may be even more effective in other domains. But in a wider aspect, the hybrid methodologies appeared to be more efficient and effective.

I. INTRODUCTION

Computer Science is now getting more and more involved in the medicine and health sciences. The branch of computer science which is more actively and efficiently involved in medical sciences is Artificial Intelligence. Various Clinical Decision Support Systems have been constructed by the aid of Artificial intelligence. These systems are now widely used in hospitals and clinics. They are proved to be very useful for patient as well as for medical experts in making the decisions. Different methodologies are used for the development of those systems. The way of gathering the input data and to present output information's is different in different methodologies. Any computer program that helps experts in making clinical decision comes under the domain of clinical decision support system. An important characteristic of the Artificial Intelligence is that it can support the creation as well as utilization of the clinical

knowledge. Using Artificial Intelligence we can make the systems that will have the capacity to learn and the creation of new clinical knowledge. The main objective of this paper is;

- To present recent trends in Clinical Decision Support Systems.

- To discuss methodologies used in Health Care.

II. HISTORY OF DECISION SUPPORT SYSTEMS IN MEDICINE

Since computer was invented, it has been used for assisting medical professionals. The first research article dealing with medicine and computers appeared in late 1950s (Ledley & Lusted, 1959). Later an experimental prototype appeared in the early 60s (Warner et al., 1964). At that time limited capabilities of computer did not allow it to be a part of medical domain. In 1970s the three advisory systems: de Dombal's system for diagnosis of abdominal pain (de Dombal et al., 1972), Shortliffe's MYCIN system for antibiotics selection (Shortliffe, 1976), and HELP system for medical alerts delivery (Kuperman et al., 1991; Warner, 1979). 1990s witnessed a large scale shift from administrative systems to clinical decision support systems [57].

III. METHODOLOGY

The case study is based on the analysis and comparison of various methodologies used in clinical decision support systems. The data for the case study is obtained from the results and work of various researchers on Decision Support Systems. The initial conduction of the case study involved reading 60 research papers. These research papers were extracted from web using different search engines such as IEEE, Springerlink, CDMA Digital Library etc. The keywords used for accessing those research articles are "Clinical Decision Support Systems, Pain Management", "Compute Aided Systems, Pain" and "Clinical Decision Support Systems". Some of them are Journal papers whereas others are presented in Conferences. Among 60 papers, 10 appear to be irrelevant, 10 appear to be fully medical based and the remaining 40 are relevant to Clinical Decision

Support Systems. These 40 research papers are then analyzed and evaluated on the basis of methodology used in them. Graph 1.1 shows different search engines used for article extraction and number of articles extracted from each search engine.

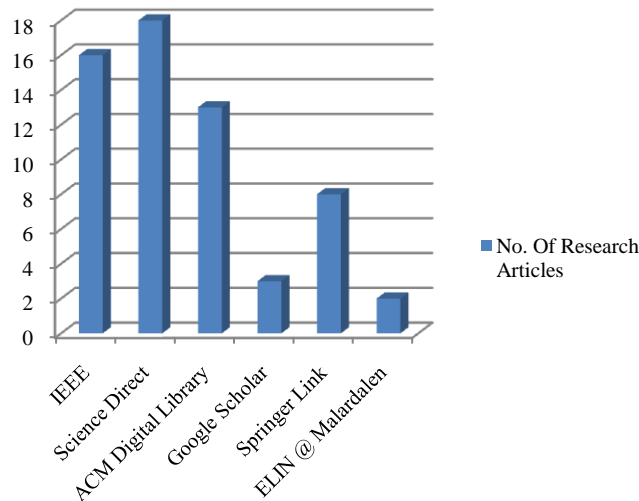


Fig.1.1 representing different search engines used for extraction of research articles and number of articles extracted per search engine.

IV. DECISION SUPPORT SYSTEMS USING ARTIFICIAL INTELLIGENCE

Artificial Intelligence is an integral part of Decision Support Systems. Decision Support Systems that are implemented with the aid of Artificial Intelligence have the ability to adopt in new environment and to learn with time [28], [29]. Various methods are used to gather information used for the process of Decision making in Computer Aided Support Systems/ Expert Systems. These methods include Statistical Method, Neural Network, Knowledge Based Methods, Fuzzy Logic Rule Based, Genetic Algorithms etc. The selection of a particular methodology depends upon various parameters such as

- What is the problem domain?
- What can be the solution?
- Amount of data available.
- Researcher choice and purpose.

For the diagnosis of pain, medical science need computer aided software that can collect the health related signals from patients and transform them in pain intensity [6]. Pain causes

degradation in the life of patients and due to lack of the proper evaluation methods, sometime patient stops asking for further medication as the pain becomes worse [30]. Similarly the critical monitoring of the patient after operation needs accurate measurement of the medicine proportion as over dosage can sometime result into threats of life [2]. The use of a Clinical Decision Support System to measure the intensity and diagnose the pain is much more efficient, effective and economical.

The use of the Clinical Decision Systems in surgery is also very common. Minimal invasive surgery is a preferred method for operations today. The development of a reliable flexible fiber or wave guide will enable surgeon to bring laser beam transendoscopically within body cavities. It combines the endoscopy technique with the advantageous laser interaction with tissue to create a powerful surgical tool for operating procedures. It lower cost, fastest healing and minimal post operative pain [5].

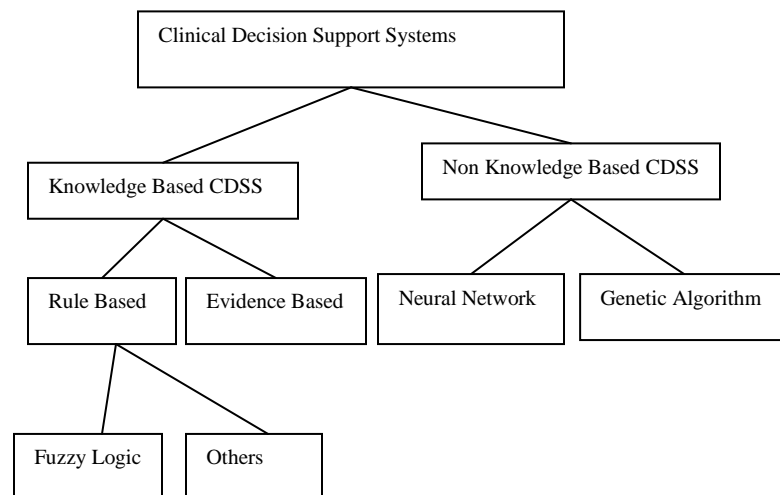


Fig.1.2 representing different methodological branches of the Clinical Decision Support Systems.

V. TYPES OF CLINICAL DECISION SUPPORT SYSTEMS

Clinical decision support systems are broadly classified into two main groups.

- Knowledge based CDSS
- Non-knowledge based CDSS

1. Knowledge Based CDSSs:

The knowledge based clinical decision support system contains rules mostly in the form of IF-Then statements. The data is usually associated with these rules. For example if the pain intensity is up to a certain level then generate warning etc., The knowledge based generally consists of three main parts. Knowledge base, Inference rules and a mechanism to communicate. Knowledge base contains the rules, inference engine combines rules with the patient data and the communication mechanism is used to show the result to the users as well as to provide input to the system. In certain case, such as of chest pain management, the adaptive guidelines from a knowledge base server prove to be much more effective than others [11].

They are the commonest type of Clinical Decision Support System used in clinics and hospitals. They can have clinical knowledge about a specially defined task, or can even be able to work with case base reasoning. The knowledge within expert system is generally represented as set of rules. Sometimes the knowledge based is used with variance management to execute patient care process and provide high quality health care services dynamically. This knowledge based management system is implemented using the object oriented analysis, UML techniques and handling of variance through the construction of generalized fuzzy ECA (GFECA) rules. [16]

Types of Knowledge Based

1.1 Fuzzy Logic Rule Based:

It is a form of knowledge base and has achieved several important techniques and mechanisms to diagnose the disease and pain in patient. For example RVM Learning Technique is used for pain management in patient who cannot communicate verbally. The pattern recognition technique can assist medical staff in measuring the pain which is an extension of Vector machine algorithm. [10]. The Fuzzy Logic Rule based classifier is very effective in high degree of positive predictive value and diagnostic accuracy. For example in diseases like appendicitis, the results predicted by fuzzy logic rule based classifier have an accuracy rate of 95% on average [12]. For improving the effectiveness of fuzzy set theory, Rough set theory can be proposed to complement fuzzy set and to deal with vagueness and uncertainty. Its main advantage is that it does not need data such as probability distribution in statistics, basic probability assignment, and grade of membership of value of possibility

in fuzzy set theory [14]. Clinical guidelines provide benefits to health outcomes and are economical but they have certain characteristics that are difficult to handle such as vagueness and ambiguity. Fuzzy logic facilitates us for treatment of vagueness in decision support system. Fuzzy logic approach can be a very useful approach for describing vagueness and imprecision in precise mathematical language, explicitly representing clinical vagueness [28].

1.2 Rule- Based Systems & Evidence Based Systems

They tend to capture the knowledge of domain experts into expressions that can be evaluated as rules. When a large number of rules have been compiled into a rule base, the working knowledge will be evaluated against rule base by combining rules until a conclusion is obtained. It is helpful for storing a large amount of data and information. However it is difficult for an expert to transfer their knowledge into distinct rules.

For closing the gap between the physicians and CDSSs, evidence based appeared to be a perfect technique. It proves to be a very powerful tool for improving clinical care and also patient outcomes. It has the potential to improve quality and safety as well as reducing the cost [34].

2. Non Knowledge Based CDSS:

CDSS without a knowledge base are called as non-knowledge based CDSS. These systems instead used a form of artificial intelligence called as machine learning. Non-knowledge based CDSSs are then further divided into two main categories.

2.1 Neural Network:

To derive relationship between the symptoms and diagnosis, neural networks use the nodes and weighted connections. This fulfills the need not to write rules for input. However, the system fails to explain the reason for using the data in a particular way. So its reliability and accountability can be a reason. It has been observed that the self organizing process of training the neural network in which it isn't given any priory information about the categories it is required to identify, is capable of extracting relevant information from input data in order to generate clusters correspond to class. Furthermore it requires only a small proportion of available data to train the network [1]. In identifying the pain in infant child, neural networks extract the two features MFCC and LPCC from infant cry and are fed them into recognition

module. The accuracy rate of this system under different parameters reported as 57% to 76.2% [13]. The neural networks are also very important especially in complex multi-variable systems to avoid costly medical treatment and for diagnosis of pain [19].

Advantage:

It does not need any input from experts. Eliminating the need of expert helps the system to eliminate the need of large databases to store input and output. It can work on incomplete data by guessing the data based on the successive data trend.

Disadvantage:

Disadvantage can be that sometime the training process needs too much time. They combine data based on statically recognition patterns with time which is difficult to explain.

Neural Networks have been widely applied to non-linear statistical modeling problem and for modeling large and complex databases of medical information. Goal of training is to optimize performance of network in estimating output for particular input space. Back propagation training algorithm, a popular approach used with medical databases adjusts weight of an ANN to minimize a cost function. The ANN maintains correct classification rates and allows a large reduction in complexity of the systems. The use of the weight-elimination cost function is well enough to overcome the network memorization problems [24].

2.2 Genetic Algorithms:

They are based on evolutionary process. Selection algorithm evaluates components of solutions to a problem. Solution that comes on top are recombined and the process runs again until a proper solution is observed. The generic system goes through an iterative procedure to produce the purpose the best solution of a problem.

It has been observed that none of the case, studied in this paper used genetic algorithm which means researcher miss the opportunity to take the advantage of genetic algorithm. It also explains that there is a scope to implement clinical decision support system using genetic algorithms. This can be topic of future work.

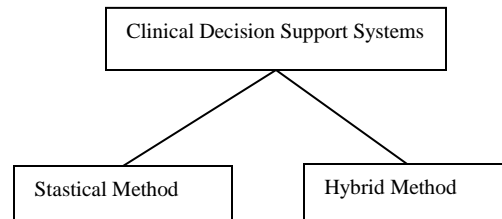


Fig.1.3 representing two modern trends of implementing the clinical decision support systems. They do not lie under the clinical decision support system tree of Fig.1.2. However they can be considered as its subsection.

Statistical Method:

It is one of most simple and useful method used for data collection. It can be in the form of a survey, experiment result or questionnaire. Development of clinical decision support systems using statistical method as an integral part is very common [6]. For example to focus the economics of post operative pain with focus on opioid and the local regional anesthetic, a bibliographic database survey can be a good option [6]. Data can be collected as a questionnaire mentioning the status of patient how he looks like, its way of talking, what he feels and many more. It can be a better way of quantitative and qualitative assessment of postoperative pain [39].

Hybrid Systems:

A combination of two or more methodologies within a design of single system results into a hybrid system. Hybrid systems extract the best from all methodologies and provide an optimal solution for clinical decision support systems [18]. For example to identify the clinically relevant aspects of MEDLINE automatically, the combination of knowledge-based and statically techniques can be good approach. The extracted elements then served as an input to the algorithm to score a relevance of citations with respect to structured representation of information needed, based on the principles of evidence based medicine. The principles of evidence based medicine can be captured computationally and implemented in a system. It has the potential of improving the quality of health care [18]. Meta reasoning method such as hybrid systems consists of different reasoning methodologies. It can consist of a rule based, case based and model based reasoning. That finally results into an overall improvement of the system performance [31].

VI. RELATED WORK

Several studies have been conducted by health professionals and researchers to find out the characteristics of Decision Support System and what can be a good methodology in the design of a decision support system. A randomized and non randomized controlled trial exercise is used to evaluate the effect of CDSS compared to without a CDSS on practitioner performance.

The data from hundred subjects has independently abstracted by the reviewers. It was observed that in most of the cases Clinical Decision Support Systems improve the practitioner performance [33]. On comparing the diagnostic accuracy of computer program with emergency room physician, by using 132 subjects, the result appears to be very much promising and encouraging [36].

Evaluation of the Decision Support System to tackle the sensitivity of the medical equipments is an area of concern for most health physicians. The use of a hybrid Bayesian method and a statistical approach can be a better methodology to evaluate system performance [32]. The similarity between this case study and the case study conducted other researchers is the approach of abstracting the data from present and past research. The difference can be that no survey or case based study covers as many domains of knowledge and non knowledge base methodologies as this paper.

VII. FINDINGS

TABLE II
FINDINGS OF CDSSs CASE STUDY

Sr. No	Article	Purpose	Work Method	Application Domain
1	[1]	Pain Detection, Diagnosis	Artificial Intelligence	Discogenic Pain
2	[2]	Avoidance of Over dosage of Medicine	AI (Neural Network)	Respiratory Mechanism
3	[3]	Surgical Healing Process	Artificial Intelligence	Anatomy
4	[4]	Safety Interlocks to avoid severe complications	Artificial Intelligence	Respiratory Mechanism
5	[5]	Post Operative Pain Diagnosis, Cost Reduction	Artificial Intelligence	Surgeries & Operations
6	[6]	Post Operative Pain Management, Data Mining	Artificial Intelligence	Surgeries
7	[7]	Post Operative Pain Diagnosis, Cost Reduction	Opioid Sparing	Medicine
8	[38]	Post Operative Pain Diagnosis, Stable Pain Score	Ketamine plus 2/3 Morphine	Medicine
9	[8]	Stable Pain Score, Reduced Opioid Requirements	Medicine	Children Surgeries
10	[9]	Healing Wound Inflation	Medicine	Health Care (Post Operative Pain)
11	[10]	Pain Assessment, Sedation Level	Artificial Intelligence	Infant Patients

12	[11]	Pain Diagnosis	AI (Knowledge Based)	Chest Cancer
13	[12]	Data Mining, Disease Diagnosis	AI (Fuzzy Logic Rule Based)	Appendicitis
14	[13]	Pain Recognition	AI (Neural Network)	Infant Child Diseases
15	[14]	Vagueness & Uncertainty	Rough Set Theory	Artificial Intelligence
16	[15]	Cost Reduction	AI (Knowledge Based)	Multidisciplinary Web Based
17	[16]	Object Oriented Analysis, Design Techniques	AI (Knowledge Based)	Health Care Services
18	[17]	Pain Diagnosis	AI (Web Based CDSS)	Health Care (Lower Back)
19	[18]	Effective Clinical Decision Support System	AI (Knowledge Based Hybrid)	Medical Health Care
20	[19]	Uniary Tract Disease Prediction, Classification & Diagnosis	AI (Neural Network)	Urology Diseases
21	[20]	Pain Diagnosis Decision Making	Artificial Intelligence	Ontology
22	[21]	Improving Clinical Decision Support System	AI (Hybrid)	Gastroenterology
23	[22]	Post Operative Pain Diagnosis	AI (Visual Analogue Scale)	Health Care (VAS Analysis)
24	[23]	Clinical Decision Support Systems Performance Improvement	Artificial Intelligence	Decision Support Systems
25	[24]	Weight Elimination, Cost Reduction, Network Training	AI (Neural Network)	Intensive Care Unit
26	[26]	Effectively Decision Making	Artificial Intelligence	Oncology
27	[25]	Post Operative Pain Management	Artificial Intelligence	Health Care Web Based
28	[39]	Post Operative Pain Management	Artificial Intelligence (VAS)	Health Care
29	[27]	Evaluation of Decision Support Systems	Artificial Intelligence	VentEx Decision Support System
30	[28]	Elimination of Vagueness & Ambiguity	AI (Fuzzy Logic Rule Base)	Decision Support Systems

31	[29]	Past, Present & Future trends	Artificial Intelligence	Clinical Decision Support Systems
32	[30]	Reduction of Medication Errors, Cost and Time	Artificial Intelligence	Computer Physician Order Entry
33	[31].	Integration of Rule Based, Case Based & Model Based Programming	Artificial Intelligence	Meta Level Reasoning, Clusters
34	[32]	Evaluation of Decision Support Systems	Artificial Intelligence	Intelligent Clinical Decision Systems
35	[40]	Pain Management	Behavioral Pattern	Artificial Intelligence
36	[33]	Pain Diagnosis, Improving Practitioner Performance	Artificial Intelligence	Clinical Decision Support System
37	[34]	Cost Reduction, Performance Improvement	Artificial Intelligence	Clinical Decision Support System
38	[35]	CAD Probability Estimation, Non Invasive Diagnosis	Artificial Intelligence	Coronary Artery
39	[36]	Pain Diagnosis	Artificial Intelligence	Chest Disease
40	[37]	Post Operative Pain Management	Artificial Intelligence	Lumbar Disc Prolapse, Physiotherapy

From Table 1.1 we can summarize the results of our case based study. Different columns of the table present different results from the papers. Article column referred to the studied research papers whereas the purpose, work methods and application domains are used to briefly explain the details of the papers. It also explains that the use of Artificial Intelligence is becoming more and more in health care.

VIII. DISCUSSION

The results of our case based reasoning showed that two different practices are generally exercised in hospitals. One can be the manual way of prescribing the medicines by health professionals after analyzing the patient history and reports. The other can be by the use of Clinical Decision Support Systems. In Clinical Decision Support Systems, System Senses the disease or pain and based on the methodology used in its implementation, it suggests the prescription [1]-[40]. On studying both practices on a relatively smaller scale, it is observed that the Clinical Decision Support Systems

have several edges over manual systems. They are efficient, effective and low cost. The case study provides an overview of the current practices regarding post operative pain and physiotherapy management of patients. The findings identify discrepancies in services provided to patients and highlight current research not always reflected in treatment provided [37]. It highlights that the difference between the correct diagnosis by program and by physicians is 72% to 79%. In some cases such as diagnosis of CAD, the computer aided program being relatively simple and reliable makes it easy for physicians to estimate probability of CAD. Whether additional non invasive diagnostic studies should be employed to improve probability of disease and to appropriately select patients to coronary angiography [35]. On comparing the clinical decision support systems with non clinical decision support systems it is observed that there is no way by which non clinical decision support systems can compete [34]. In Diseases like cancer, pain and the comorbid behavioral symptoms such as depression and cognitive

appears to decline. Patients suffering from cancer have higher risk of depression and cognitive decline [39]. Due to the sensitivity of the deploying environment, the CDSSs should be properly evaluated and tested before its actual deployment. To physician it appears to be a black box, so that should know that it's safe enough to be used [32]. Several Web based Clinical support systems such as VentEx are in used that support the process of decision making. It is a knowledge based system having domain knowledge represented by rule based; object oriented scheme and an inference engine including mechanism for generating decision support [27]. Similarly PROSPECT is an evidence based procedure-specific postoperative pain management website for clinical decision making [25]. Hybrid Decision Support Systems can be both CBR and RBR. Hybrid can be RBR first CBR last, CBR first RBR last, CBR & RBR Parallel or both are mutually exclusive [26]. Traditionally isolated, stand alone DSS has been recently facing new challenges. Research has going on to develop IDSS integrated decision support systems to have better results [23].

The Graph 1.2 shows different methodologies that are used in the Clinical Decision Support Systems. The total number of research papers implementing Artificial Intelligence in decision support systems studied within this case study are 40. The graph shows that statistical methodology and the Neural Networks are the most commonly used methodologies in the designing of Clinical Decision Support Systems. Then we have knowledge based and hybrid (Combination of two or more methodologies) at the second place. Interesting observation from our study is that many researchers are using some uncommon methodologies. It shows that there are still opportunities and place for improvement in the implementation methodologies of Clinical Decision Support Systems.

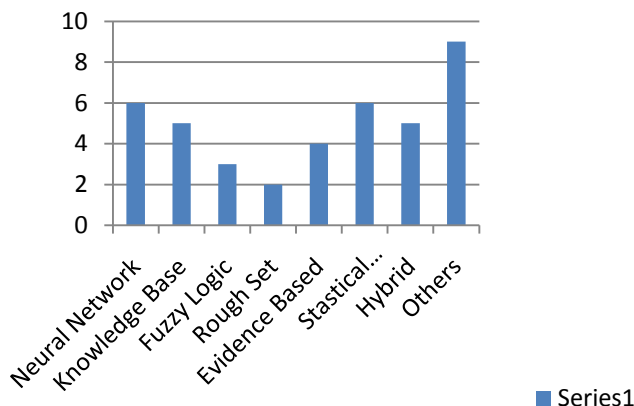


Fig. 1.4 representing different strategies used in the development of Clinical Decision Support Systems (CDSSs)

IX. CONCLUSION

Different methodologies for implementing the clinical decision support systems have been studied in this case study. By comparing these methodologies, it is observed that some techniques are domain based. They are effective only within a specific diseases area. Whereas some are on average useful in all domains. The selection of a particular methodology also depends upon some external parameters such as the cost of system, efficiency required, and amount of data available and the sensitivity of the system. From the study it can be concluded that a hybrid CDSS with two or more methodology can be a better approach.

Due to the limitation of time, there are still few aspects of clinical decision support systems remain unstudied. That makes it difficult to suggest an optimal hybrid methodology for the implementation of clinical decision support systems in this paper. In future, the knowledge from this paper can be reused as a thesis work or as a research topic itself.

X. APPENDIX

i. Thermography (pain detection, diagnosis)

It talks about the use of thermography to discogenic the lumbar disc herniation pain. It changes the pain into a color image form. It has a very high sensitivity of 89.5% and its results are very much correlated with post operative clinical results. It is very much useful to diagnose the disc herniation, detecting the symptomatic level in multiple disc herniation and to predict the post operative courses in the lumbar disc herniation. The level of the pain severity in disc herniation is different depending on the duration of symptom, types of herniation and other numerous factors. Now the new infrared thermographic imaging is very useful for differentiation of acute and chronic disc herniation.

ii. Neural Network (Training the network, Avoidance of over dosage)

It focuses on the importance of monitoring the post operative patients to avoid any life threatening after affects because of the over dosage of morphine. One way to avoid it can be studying correlation between analgesia, the airway obstruction and hypoxia. Using the neural network it is observed that even without giving any prior information about category it is required to identify, still it is able to extract the relevant information from input data to generate clusters that corresponds to class. It is recorded that even a

small amount of available data is enough for training the network.

iii. *Laparoscope (Surgical Healing process, Enhancement of 3CCD)*

It discusses the use of Laparoscopes that have certain benefits in surgical processes such as surgical incisions are small and healing process after the post operative pain is quick. Other than that it has some disadvantages such as it is very much technical in nature, it can loss the three dimensional assessment of anatomic structures. The research work on the enhancement of 3CCD camera using software algorithms to visualize is under process. Some injuries like common bile duct injury are very common complication of laparoscopic use.

iv. *Interoperable System (Respiratory System, Safety Interlock)*

This paper explains the need of an interoperable system that can continually monitor the patient on PCA system to detect evidences of deteriorating respiratory functions or critical states and suspend the medication delivery in case of over medication. It activates safety interlock and activates the nurse call.

v. *Endoscopic Imaging System (Minimize Post-Operative Pain, Cost, Powerful Surgical Tool):*

The use of the Clinical Decision Support Systems can be best observed in performing the medical operations today. Minimal invasive surgery is lower cost, fast healing process and minimizes the post operative pain. The two dimensional and three endoscopic imaging systems make it much more powerful. The use of the laser beam transendoscopically within body cavities is because of the development of reliable fiber or waveguide. The combination of endoscopy technique with the laser interaction creates powerful surgical tool. It has a long list of several WG's. The people participating in the survey are trying to have more flexible, high power and maximum reliability.

vi. *iPCA (Post-Operative Pain Management)*

Post Operative Pain is a very common complains of patients. Sometime this pain becomes so extreme that it causes more damage than the actual disease. There is a need of a Clinical Decision Support System that will enable us to continuously measure the level of pain in patient and help in its efficient management. It can be an integrated information system

iPCA consisting of three main parts. Front for sensing the data, back for pain management database and data mining from systems and a middle integration network. The paper shows the feasibility of the approach in medical domain.

vii. *Opioid-Sparing (Post-Operative Pain, Cost Effective):*

The use of the medical opioids is an important component for the management of post operative pain but it increases the cost of health care. There is a need of cost effective technique for the management of post operative pain. A survey was conducted to compare the use of Opioid only with Opioid-Sparing and it is observed that the Opioid Sparing reduced the hospital cost.

viii. *Ketamine plus 2/3 Morphine (Post-Operative Pain, Stable Pain Score):*

It compares the use of standard morphine dose to 35% lower dose plus a subanaesthetic dose of ketamine for the diagnosis of post operative pain. The patient suffering from tissues and bone cancer have severe pain during surgery. A randomized study of 10 months survey showed that the use of ketamine plus 2/3 standard dose of morphine results in more stable score of pain and shorter period of treatment.

ix. *Ketorolac (Stable Pain Score, Reduced Opioid Requirements):*

It involves the study of stable pain score in children undergoing surgeries. It was observed that ketorolac provides the analgesia comparable to the mepridine and significantly reduced opioid requirements but is not associated with the reduction of post operative vomiting of length of stay and in management of acute surgical pain.

x. *Bupi Vaccine (Wound Inflation, Pain Score)*

It is a study on the precision of wound inflation with bupi vaccine to wound at the end of the operation. A survey was conducted. The focus of survey was to divide the patients into three groups and then take their reading for 4 consecutive days after operation. It was observed that there exists no significant difference in the opioid requirement and the pain score between all three study groups.

xi. *Pattern Recognition (Pain Assessment, Sedation Level)*

The use of pattern recognition technique using RVM learning in medical sciences is growing very rapidly. It is highly useful in diagnosis of pain and diseases in those patients that cannot communicate verbally. It is an extension of support vector machine algorithm and has the ability to distinguish pain from no pain. This pain assessment system and automatic sedation system can be used along with the decision support system to figure out the level of sedation on a score 0-6. 0 represent unresponsiveness, 1 represents responsiveness with noxious stimuli, 2 represent responsive to touch or name, 3 represent calm and cooperative, 4 restless and cooperative, 5 agitated and 6 represents dangerously agitated.

xii. Knowledge Base (Rules, Recommendations, Implementation):

It focuses on the use of the adaptive guidelines extracted from the Knowledge base and to be used in the Delivery System for Clinical Guidelines. The patient test results serves as the input to the system and on matching the input against the defined rules, an optimal recommendation plan has been generated. The System then implements the suggestion in the form of an alert using the intelligent agent. The main advantage of using the Delivery System for Clinical Guidelines is the reduction in the number and length of patient stay in hospital.

xiii. Fuzzy Logic Rule Base (Data Mining, Disease Diagnosis):

The use of the Fuzzy Logic Rule Based classifier as a data mining technique in the diagnosis of diseases like appendicitis is very effective. It can accurately diagnose the severity and the type of appendicitis. The severity of appendicitis in the patient can be classified into mild, moderate and severe appendicitis depending upon various parameters like pain site, pain nature, nausea, temperature, white blood cell count etc. The accuracy rate of the results predicted by fuzzy logic rule based as an accuracy of 95% on average.

xiv. Neural Network (Pain Recognition, Training Network):

The paper discusses the use of the forward neural network architecture in recognition of pain, especially in the infant cry recognition between pain and non pain cries. For initial training of the network, conjugate gradient algorithm is used. The system extract two different features MFCC and LPCC

from infant cry and feeds it in recognition module. System accuracy of the results reported to be 57% to 76.2% under different parameters.

xv. Rough Set Theory (AI, Vagueness & Uncertainty):

A newly emerged trend in applying the Artificial Intelligence in Clinical Decision Support Systems is the use of Rough Set. The Rough Set theory deals particularly with the vagueness and uncertainty. Rough set actually complements the fuzzy set theory. Advantage in the use of the rough set theory is that it does not need any additional information about data such as probability distribution in statistics, basic probability assignment, and grade of membership or value of possibility in fuzzy set theory.

xvi. Web Based CDSS (Knowledge Based Domain, Cost Efficient):

To overcome the short comings and the limitations of the manual based clinical systems, a web based clinical system has been proposed. The manual system has several limitations such as the recordable patient information is limited, which makes it difficult to make meaningful set of clinical information and to reflect changing trend. It is based on daily expected interventions and their outcomes. The web based clinical system can make use of the knowledge based domain to provide higher quality lower cost health services. GEFCARules are constructed to handle directly the use of variances related to patients.

xvii. Knowledge Based Variance Management System (Object Oriented Analysis, Design Techniques):

The dynamically execution of the patient care process requires the efficient variance management for computerized implementation of Clinical Pathways (CP). The paper focuses on the development of knowledge based variance management system using Object Oriented Analysis & Design Techniques like UML. The system makes use of fuzzy reasoning of generalized fuzzy ECA rules and TFPN-PK in handling of variances.

xviii. Web Based Decision Support System (Knowledge Based Verification, Validation & Clinical Efficiency):

The diagnosis of the Lower back pain is a very challenging problem due to complex anatomical and physiological structure. The use of a web based decision support system can be very useful to extract patient data from distributed

places and to recommend the diagnosis. The evaluation of such results includes knowledge based verification, system validation and clinical efficiency.

xix. Knowledge Based Hybrid (Evidence Based, Statistical Based):

The use of a hybrid of a knowledge based and statistical based technique can be a better solution for physicians to automatically identify clinically relevant aspects of MEDLINE abstracts. The paper discusses the integration of the two techniques into algorithms that draw best from both domains. The explicitly coded semantic knowledge in the form of UMLs for leveraging the resources i.e, MetaMap can combine to simplify knowledge extraction tasks that would be difficult otherwise. The positive results of the experiment shows that the principles of evidence based medicine can be computationally captured and implemented in system.

xx. Neural Network (Uniary Tract Disease, Classify, Predict and Diagnosis):

It discusses the implementation of neural networks especially in multilayer perceptron. The subjective disease for this case study is lower uniary tract. The system is able to classify, predict and diagnosed the dysfunction of lower urinary tract with a degree of certainty of 85%. The initial training of ANN is done using the registers of patients. The system results in saving cost, time and diagnosis of pain in patients.

xxi. Clinical Ontology Systems (UML Interoperable Solutions, Knowledge Databases):

The subject of the paper is the clinical ontology systems and how to overcome the problems in the process of decision making. The ontology systems do not provides the semantic types which are required to create structure to carry shared knowledge database. This results in ontology interoperability problems and makes it difficult to support clinical decision making. The paper presents UML interoperable solution to contribute collaborative diagnosis decision. It uses a novel ontology, DDSOnt, facilities to create, share, search and use knowledge database through web services and RDF semantics. It helps to represent medical decision rules in knowledge databases; using rule based language as MLM and Arden.

xxii. Comparison (Knowledge Based, Statistical Based):

The paper presents a comparison between the knowledge based paradigm and statistical reasoning approach. It

describes the limitations of statistical based approach in making clinical decisions. Argue in the lack of success in statically paradigms can be because of probabilistic methodology itself is inappropriate.

xxiii. VAS (Post Operative Pain Score, Pain Relief):

The assessment of Visual Analog Scale (VAS) to check its measurability power for pain intensity, VAS ratings and the change score. An analysis of data from 2 randomized controlled trials of post operative pain is used. As expected, the amount of change correspond to different levels of pain relief, percentage change in patient VAS score was less biased by pre treatment of pain compared to absolute change in score.

xxiv. IDSS (Shift from Stand-Alone to WWW):

The traditional stand-alone systems are not sufficient enough to cope up with the new challenges of medical domain. This paper focuses on the development of integrated decision support systems (IDSS) through multiple perspectives. Much software, research papers are discussed to have a better understanding of the challenges and to help integration that will support in decision making processes. Some of the challenges can be the shift of technology from a database to warehouse and online analysis from mainframe to client/server architecture and from single user to World Wide Web. That also results in increased complexity of decision making process.

xxv. Artificial Neural Networks (Weight-Elimination Cost Function, Network Training):

Artificial Neural Networks (ANNs) are widely used in applications for modeling large and complex database. The initial training is provided to the network so that the system will get adopted to the type of data. To adjust the weights and for minimizing the cost of network, back propagation training algorithm is used. The chosen cost function is the average sum squared errors between desired outputs and the actual outputs. It was observed that the weight-elimination cost function improved the performance of ANNs as well as reducing the complexity of the system. Here the missing data is replaced by normal common values and the results were very promising.

xxvi. Clinical Decision Support Systems (CBR, RBR):

To evaluate the patient recovery period and to figure out its deviations from the norm, multidisciplinary committees have

been frequently constituted in hospitals and clinics. In case of a deviation, professionals consider the similar cases in their past experiences. This paper focuses on the construction of the Decision Support System that will compare the data according to defined guidelines and will then evaluate the results. It uses a hybrid combination of both CBR and RBR methodologies. Which can be in any of the four combinations; the CBR first-RBR last, the RBR first CBR last, CBR and RBR parallel or both of them mutually exclusive.

xxvii. *PROSPECT (Evidence Based Procedure, Post Operative Pain Management):*

To improve the health and the way of living of humans, several websites are designed to provide information and to recommend the patient on the diagnosis of post operative pain management. PROSPECT is one of them that utilizes the evidence based procedure for postoperative pain management. It also takes into account the transferrable evidence from other appropriate surgical procedures and takes account of the currently accepted clinical practices. It offers a number of alternative evidence based recommendation for each procedure.

xxviii. *Post Operative Pain Management (Statistical Based, Visual Analogue Scale):*

It focuses on the use of statistical based methodology for the collection of data for assessing the post operative pain. To measure the intensity of pain, a visual analogue scale is used. The research design of this study is classified as explorative, descriptive, qualitative and contextual design. An important aspect of the study was that different cultural groups experience the pain differently.

xxix. *VentEx Knowledgebase System (Rule based, Object Oriented Schemes):*

VentEx is a medical knowledge based system that supports decision making in management of ventilator therapy. The main focus of this paper is to evaluate the performance of VentEx compared to physician's advice. It consists of a knowledge based system having the domain knowledge represented by rule based, object oriented schemes and an inference engine including mechanism for generating decision support.

xxx. *Fuzzy Logic Based (Vagueness, Ambiguity):*

Vagueness and ambiguity in natural clinical guidelines are very common problems which are difficult to handle. Fuzzy logic appears to be the only solution for the treatment of vagueness in decision support systems. The paper focuses on addressing the uncertainty issue in practice guidelines. Uncertainty can be because of lack of information, non specification, probabilistic nature of data and outcomes etc. Fuzzy logic is used for describing the vagueness and imprecision in precise mathematical language, explicitly representing clinical vagueness. Evidence based guidelines provide as bottom line the NNT and cost of treatment.

xxxi. *Clinical Decision Support Systems: (Past, Present & Future):*

The paper discusses the historical use of Computer Based Clinical Systems for billing and administrative purposes. The change of the trend in early 90s made the computer systems to facilitate the health professional in disease and pain diagnosis. Then it describes the future scenario to see the computer aided systems as fully independent system to assess the disease and to diagnose them. These systems will have the capability to self organize, self learn, fault tolerance, error handling and much more.

xxxii. *Computer Physician Order Entry (CPOE) (Medication Errors, Cost & Time):*

Pain increases the intensity of the disease and in some cases it even becomes more acute than the original disease. The use of the old decision support systems is not enough reliable to always recommend the correct diagnosis. Medication errors sometime improved medication cost as well as time period. The use of a Computer Physician Order Entry (CPOE) system coupled to a Decision Support System (DSS) is a good and improved way of avoiding the deviation from guidelines and to have a less cost and less treatment response time.

xxxiii. *Meta-Level Reasoning (Integration of Rule Based, Case Based & Model Based Reasoning):*

The development of the architecture that will enable the integration of several reasoning methods to get the best from all domains and to have an optimal decision support system is the focus of the paper. The design of the architecture is related with meta-level reasoning to apply Artificial Intelligence in the integration of rule based, case based and the model based reasoning. There is a significant amount of meta reasoning in relation to the CBR systems. This paper

focuses on an introspective approach to meta-level learningxxxviii. that allows the gradual addition of meta reasoning methods on broad, evolves the architecture and address utilization of clinical guidelines in an efficient manner.

xxxiv. *Clinical Decision Support Systems (Artificial Intelligence, Bayesian Networks):*

The evaluation of the decision support systems is an issue of major concern. To physician the system appears to be a black box. They do not understand the technicalities of the system. So the designer should realize the sensitivity of the application and the harm they can cause in patient. Different Artificial Intelligence techniques along with Bayesian networks are used to evaluate the performance of Decision Support Systems. This is sufficient enough to deal with problems and help the researcher in evaluation of Decision Support Systems.

xxxv. *Pain (Behavioral Pattern, Management):*

Extreme pain in patient suffering from diseases like cancer etc., sometime appears as depression and cognitive decline. Pain affects the behavior pattern of the patients. So the better assessment and management of pain requires a very organized approach to identify physical, emotional and cognitive dimensions towards the significant improvement.

xxxvi. *Clinical Decision Support Systems (Pain Diagnosis, Practitioner Performance):*

A survey has been conducted to evaluate the performance of Clinical Decision Support Systems in diagnosis of patient pain and the improvement of practitioner performance. The data has been collected statistically by the team of researchers and a significant improvement in the practitioner performance and pain diagnosis was observed.

xxxvii. *Clinical Decision Support Systems (Evidence Based Medicine, Cost Reduction):*

The paper focuses on minimizing the distance between the physicians and the evidence based medicine. The systems should be able to facilitate the physician in making decisions. It should be able to prevent the error made by the users and should have the capability to self organize itself. The result gathered by using the evidence based practice proves that it has the potential to improve the quality and safety of life along with a major reduction in cost. The implementation of computerized decision support system through electronic medical record can be a key to it.

Clinical Decision Support Systems (Estimate CAD Probability, Non Invasive Diagnosis):

The lower prevalence of CAD caused limitations in the diagnostic accuracy of clinical history and non invasive testing methods. The focus of the paper is to improve the diagnostic value of history, ECG exercise testing and stress perfusion. A system has developed to aid the cardiologist in interpreting the clinical data and results. The results showed that the Clinical Decision Support System makes it easy for the physicians to estimate probability of CAD present, to decide about the additional non invasive diagnostic studies to improve probability estimate of disease and to appropriate select patients to submit to coronary angiography.

xxxix. *Clinical Decision Support Systems (Diagnostic Ability):*

It focuses on the diagnostic ability of the computer programs on comparing it with the emergency room physicians. It was observed that the difference between correct diagnosis by program and physicians is (72%) to 79%. Despite the fact that the computer aided programs did not able to distinguish all the diseases, still the results were very much promising.

xl. *Statistical Methodology (Lumbar Disc Prolapse, Physiotherapy):*

The aim of the study is to observe the clinical effectiveness of discectomy for treatment of lumbar disc prolapse. Using statistical methodology, a questionnaire is posted to different physiotherapy departments. The findings identify the discrepancies in services provided by patients and highlight current research not always reflected in treatment provided. Most of the patient receives physiotherapy in initial stage but the amount of physiotherapy treatment is variable.

For Non Relevant Papers:

It has been found that the remaining papers are either irrelevant or they are purely medical. The main focus of this case study is to study those research articles that involved some kind of Artificial Intelligence or learning in the implementation of clinical decision support systems. Purely medical means it involves some kind of medication for diagnosis of disease whereas irrelevant means that they belongs to some other study domain such as industry etc. They lie out of our scope of case study but being a part of our study they are still a part of our reference list.

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