SYNOPSIS OF THE THESIS

“Ontology Based Online Expert System for Emergency Medicine”

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Abstract

In order to provide immediate and urgent care to the critically ill patient, there is an overwhelming need for efficient and well-prepared guidelines for the emergency service provider. Specifically, developing countries like India, are facing lack of well trained and experienced medical professional in rural area. In addition to this doctor to patient ratio in these countries are also poor and declining day by day with rise in population. With novel and well-defined policies of government has tried to address this issue at certain extent. Even though, because of socio-economical condition, geographical situation, unavailability of well-trained EM staff and lack of medical experts in the rural area, the people living in this part of the countries are still not getting enough medical facilities. Computer based expert systems are very well known since long time for assisting the individuals in absence of experts by utilizing the knowledge which they possess. Expert systems have found application in various fields. Medical field is also an important sector where these knowledge-based computer systems can prove to be a boon for saving the lives of people. But these systems depend on the individual competency and effectiveness of designing the system based on individual perspective. This puts a limitation of making the whole system rigid and unscalable. This often results in inefficient and nonreliable system in terms of decision making skill. Semantic web is the new concept introduced by the scientists to make the machine interpretable web which helps the machine to infer new information based on available information over the web. Ontologies are prime component of semantic web, which is used to model the available information in semantic form. Ontologies are based on a shared and consensual domain knowledge agreed by a community. Ontology is expressed by languages known as OWL (Ontology web language). One of the popular way of describing ontology is expressing it in terms of RDF (Resource Description Format). Ontology provides a way of expressing data in generic, extended and integrated form and makes the overall system flexible and scalable.

The system proposed here utilizes the java based client-server MVC architecture. JENA API is used here for the purpose of integration between knowledge-base stored in OWL format with JAVA servlet. The additional database related to patient, disease and treatment is stored in MySQL database. This system takes the most basic vital parameter needed for primary assessment of patient’s condition from the EM paramedic from client side and passes this information to server side where the primary risk level stratification will be calculated by the ontology and score is available to the paramedic. The secondary assessment asks additional parameters to the paramedic and generates a list of probable disease from the ontology. This system also displays the interactive steps of carrying out the treatment.
b. Brief description on the state of the art of the research topic:

1. Emergency medicine and Early warning scoring system

Emergency medicine is very important in every country because it saves the life of citizens. It primarily includes Rapid assessment, timely treatment and immediate transport of the patient to nearest hospital. Most of the people suffering from acute diseases mostly die because of unavailability of primary care. In addition to this primary care also lacks the trained professional in the rural region in developing countries. This puts limitation to proper health care facilities to all people. Government is constantly trying to address and solve such issues by forming new and advanced health policies, but still the implementation lacks the proper infrastructure and trained professional in such a heavily populated country. Timely initiation of primary treatment mainly depends on the knowledge of paramedic and other medical staff available in ambulance. In order to assist them it’s very much essential to provide them some knowledge based expert system which can help them to at least prioritize the risk level of patient and to initiate treatment and transportation to nearest available health care facility.

Clinician and researcher require robust method for prediction in critically ill patient. There are varieties of scoring system developed for this purpose in intensive care unit (ICU), emergency department (ED), and pre-hospitalization (PH). ED based scoring system considers lesser parameters which are readily available from the patient, while ICU scoring system includes more parameters which are generally available from patient admitted in ICU. Pre-hospitalization based scoring system is also designed in line with the ED scoring system.

Generally, it is believed that the scoring system with larger number of parameters should perform better than lesser parameter-based scoring system. But in some cases, scoring system with lesser number of parameters performs better than system with higher number of parameters if the population is well defined. Furthermore, some of the ED-based scoring system performs even better in ICU as compared to ICU scoring system. Pre-hospitalization scoring system also includes lesser parameters and used to define the level of criticality in the patient as a part of primary decision-making process.

2. Expert system and commonKADS methodology

The decision support systems can be broadly classified into two categories: Decision Support System (DSS) and Expert system (ES). DSS is an interactive system that helps decision-makers to utilize data and models to solve unstructured or semi-structured problems. ES is a problem-solving computer program that achieve good performance in a specialized problem domain that is considered difficult and requires specialized knowledge and skill. Both types are intended for decision making process, even though they are slightly different from each other. ES can be further classified in various categories. Amongst which most popular ES are: Rule-based system, Knowledge based system, Case-based system, Agent-based system and ontology-based system.
based system. Expert-systems are widely used in healthcare either predicting or diagnosing diseases. They are particularly useful when medical professional is unavailable. Clinical Decision Support System (CDSS) is an electronic system designed to aid directly in clinical decision-making process. So, it makes the system valuable to the clinicians in order to improve the quality of healthcare. CDSS is active knowledge system which uses two or more items of patient data to generate case-specific advice. CDSS has long existed in the medical field since 1950s to improve healthcare quality. CDSS can be consider of two types: knowledge based and non-knowledge-based system.

This commonKADS framework includes six models to construct the knowledge-based system. These models are Organizational, Task, Agent, Communication, Knowledge and Design model. This particular framework is proposed to develop generalized emergency medicine DSS with ability to provide decision on clinical risk to the patient and disease probability with treatment options. The modelling approach to construct Knowledge Base Systems (KBS) becomes well accepted among the Knowledge Engineering (KE) communities due to its modular structure and ability to break down the knowledge engineering problem into smaller tasks.

3. Ontology

The most popular definition of ontology was proposed by gruber (1993) defined is as “a formal, explicit specification of a shared conceptualisation”. In this definition, Gruber sited more emphasis on formalising the specification of concepts and relations, ultimately it allows representation of knowledge and sharing that amongst different agents. Later Studer et al. (1998) analysed this definition and perceived four main concepts: formal, explicit, shared and conceptualisation. Formal means ontology should be machine readable format; explicit implies that all concepts, properties, relations, functions, constraints and axioms used are defined explicitly; shared indicates that an ontology should capture consensual knowledge accepted by the communities; and conceptualization refers to an abstract model and simplified view of some phenomenon in the world that we want to represent. Guarino (1998) has also given another definition of ontology: “a set of logical axioms designed to account for the intended meaning of a vocabulary”. Where, Guarino focused on the role of logic theory as a way of representing an ontology.

The first step in the process of developing ontology requires concepts, attributes, relationship and axioms as a part of analysis phase. The second step includes defining conceptual model for a set of tasks identified. In the later phase of development, one has to identify most suitable ontology language to formalize the ontology and to update the ontology as per the concepts in domain in the maintenance phase. The ontology proposed in this study covers the emergency care services where the focus is on primary risk level stratification based on minimal set of data available from the patient.

Ontologies are essential component of the semantic web. It provides a shared a common vocabulary to support the sharing and reuse of knowledge. Protégé is free,
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open-source ontology editor and a knowledge management system. It provides a
graphic user interface to define ontologies. It supports ontology creation, visualization
and manipulation in various formats.

c. Definition of the Problem

Providing timely primary care to the patient in emergency situation is the most important
aspect for saving the patient’s life in that situation. There is definite requirement of the
generalized and upgradable expert system in emergency health care sector to facilitate the
EM-paramedic staff. Particularly in developing country, i.e. India with this geographically
widely spread population, demands serving better health care facility in rural area as well.
But due to lack of sufficient medical professional and trained medical staff in the rural sector,
there is a requirement of assistance from the computer based expert system. This system
needs to be generic and upgradable by utilizing the modern state of art open-source
technology.

d. Objective and Scope of work

The main goal of the present work is to develop the framework/architecture of expert system
which can assist the Emergency Medicine Practitioner to take the decision about the risk level
of patient. In emergency medicine, it is mainly important to take timely decision and initiate
therapy in order to reduce the further deterioration of patient’s health. The secondary
objective of this proposed system is to suggest possible decision about the probable disease
and also to guide for the treatment procedure of the suggested disease. The main objectives
are:

- To perform the risk level stratification of patient based on physiological parameters
  frequently monitored as a part of ambulatory care in emergency medicine department.
- To suggest the probable disease based on minimum visually observable parameters of
  patient.
- To show the interactive treatment guidelines of suggested disease.

e. Original contribution by the thesis.

The main contribution of the research is as given below:

- An extensive and comprehensive literature review is undertaken in order to identify
  the research gaps and research issues in the emergency medicine sector with the focus
  on expert system.
- The detailed literature review of expert system and their efficacy in the medical filed
  was explored to identify its impact on diagnostic procedure.
- Experts in the medical field was interviewed many a times to elicit the knowledge
  needed for proposing and designing the architecture of knowledge-based system.
The thesis is aimed to suggest a probable framework of ontology-based expert systems in the emergency medicine field.

The ontology is developed for risk level stratification based on the Early Warning Scoring (EWS) system suggested by the Royal College of Physicians. The ontology also takes the decision about differential diagnosis based on an assessment tool most widely utilized by the emergency service providers. The main assessment tools are Perfusion status assessment, Respiratory status assessment, and GCS score for conscious state assessment.

The system is implemented on an open-source JAVA-based MVC architecture. This proposed system can be very much helpful to the emergency medicine paramedic for taking decisions based on minimum number of physiological parameters and visually observable symptoms for initiating timely treatment.

The proposed system was tested on an actual database of students in one of the well-known multi-speciality hospitals for its success rate.

f. Methodology of Research, Results / Comparisons:

In order to make the proposed system, it needs to construct the knowledge base of the suggested expert system. For that the first step is to propose the various models of commonKADS framework. The subsequent section discusses these models in detail.

1) commonKADS model creation:

i) Organizational Model:

An organizational model provides an analysis of the socio-organizational environment in which the KBS will have to function. In this context, the model proposed here includes the major contributors helping to develop this emergency medicine DSS. As shown in Fig 1, the knowledge engineer gets the knowledge from the knowledge providers which is the main source of information for this particular system. In this case, doctors, EM experts, and scientists are the knowledge providers. The gathered knowledge is structured and organized in a systematic way by the knowledge engineer and with the help of the knowledge system developer, the computer-based EM-DSS will be designed and implemented. DSS will assist the end-user, in this case, they are EM-staff, to take necessary, relevant, and quick decisions based on the information available with them and ultimately to facilitate the patient.
ii) Task Model

This model specifies how the function of the system can be achieved by performing number of tasks. An identified task can be decomposed in to sub-tasks. Each separate task is described through an input/output specification, where the output represents the goal that is achieved with the task and the input is the information that is used in achieving the goal.

For the given system as shown in fig 2, three main tasks are identified: i) Clinical risk detection ii) EM score-based disease forecasting iii) Treatment suggestion. Clinical risk detection is based on score calculated from early warning scoring system. EWS is a triage-tool for taking a primary decision, in emergency department or in intensive care unit, based on the values of major vital parameters of patient. This individual score helps to calculate the total aggregate score. Based on the total score the risk level of individual patient can be accessed. This risk detection task also takes the information from the priorities and disease classification defined by emergency medicine guidelines. Second important task is forecasting of probable disease based on the calculated score and decision ontology. This ontology is developed by the knowledge engineer by eliciting knowledge from the domain experts. Third task will be carried out by rule based expert system designed from the data of clinical risk, disease and other historical data of patient.

iii) Agent Model

Agent model represents all the agents which participates in a problem-solving process. So, this model specifies who does the tasks specified in a task model. It describes the characteristics of agents. Agent in commonKADS has a generic connotation: an agent can be human being, a robot or a software program.

As depicted in fig 2, total four agents are needed to achieve the tasks listed in task model. First task needs two agents and second & third task needs one agent respectively. For a clinical risk detection, score calculated by the emergency medicine based EWS plays a main role. This task is performed by the first agent, where the
actual clinical risk detection task is performed. Second agent called EM disease classification will also help to assess the priorities involved in clinical risk. For disease prediction, EM based decision ontology along with disease forecasting agent (third agent) helps to gather disease probability. Fourth agent, rule based expert system, helps to identify the possible treatment based on the disease condition and risk levels of individual patient.

**iv) Communication Model**
In knowledge-based system, communication model becomes more important than in normal expert system. This model indicates the communication between agents.

In fig 2, the third agent requires data from the second agent in order to do disease forecasting. In addition to this, agents require database from the external world, that is also indicated in fig. The communication model basically gives the direction of flow of information amongst the agents and with the outside world too.

**5) Knowledge Model**
This is probably the most important model amongst other models of commonKADS. This model also refers to as expertise model. It contains three knowledge categories: Domain layer, Inference layer and Task layer.
In Domain layer all domain-specific knowledge is modelled which is needed to solve the task at hand. It includes conceptualization of domain in a domain ontology. Inference layer describes the most basic reasoning steps. Task layer specifies the goals of reasoning process and the strategies to achieve these goals.

In order to construct the Knowledge Model, it requires three stages to be followed: i) Knowledge Identification ii) Knowledge Specification iii) Knowledge Refinement.

This model particularly depends on the knowledge available with the experts. It requires to get as much as information available from the domain expert and convert that knowledge into appropriate form. For that purpose, it proposes a knowledge elicitation form (Table 2) for different diseases of Emergency Medicine department. The knowledge Engineer has to acquire all this information from the expert. Table 3 also lists the most commonly practised treatment in EM department as a part of primary treatment of the patient. While Table 1 helps to stratify the clinical risk detection based on the score calculated by the EWS based on aggregate score calculated from the NEWS scoring system.

**Table 1: NEWS table for score calculation and clinical risk determination**

<table>
<thead>
<tr>
<th>Physiological Parameters</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration rate</td>
<td>≤8</td>
<td>9-11</td>
<td>12-20</td>
<td>21-24</td>
<td>≥25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>≤91</td>
<td>92-93</td>
<td>94-95</td>
<td>≥96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any supplemental oxygen</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>≤35.0</td>
<td>35.1-36.0</td>
<td>36.1-38.0</td>
<td>38.1-39.0</td>
<td>≥39.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>≤90</td>
<td>91-100</td>
<td>101-110</td>
<td>111-219</td>
<td>≥220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Rate</td>
<td>≤40</td>
<td>41-100</td>
<td>51-90</td>
<td>91-110</td>
<td>111-130</td>
<td>≥131</td>
<td></td>
</tr>
<tr>
<td>Level of Consciousness</td>
<td>A</td>
<td>V,P or U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2: Knowledge elicitation form for diagnosis of EM disease

<table>
<thead>
<tr>
<th>Disease Name:</th>
<th>Chronic obstructive pulmonary disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological</td>
<td>HR: 97 BPM</td>
</tr>
<tr>
<td></td>
<td>RR: 17 per minute</td>
</tr>
<tr>
<td></td>
<td>BP: 160-120 mmHg</td>
</tr>
<tr>
<td></td>
<td>BT: 35.5°C</td>
</tr>
<tr>
<td>SPO2:</td>
<td>92.4 %</td>
</tr>
<tr>
<td>Age dependencies:</td>
<td>Yes</td>
</tr>
<tr>
<td>Prior History of patient and its relevance to the disease:</td>
<td>Yes (Social circumstances, quality of life, current treatments, smoking)</td>
</tr>
<tr>
<td>EM category (Priority)</td>
<td>High</td>
</tr>
</tbody>
</table>

### Table 3: Knowledge elicitation form for possible treatment of EM disease

<table>
<thead>
<tr>
<th>Primary treatment</th>
<th>IV lines: Hydrocortisone 200mg IV may be given initially if the oral route is not appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of possible therapy</td>
<td>Medication: Antibiotics (Amoxicillin 500 mg oral tds)</td>
</tr>
<tr>
<td></td>
<td>Defibrillation: Not required</td>
</tr>
<tr>
<td></td>
<td>Airway management: Bronchodilators (Nebulised salbutamol 5mg and ipratropium bromide 500 NIPPV (Positive Ventilation) micrograms should be given on arrival and repeated 4-6 hourly.)</td>
</tr>
</tbody>
</table>

#### NEWS scores

<table>
<thead>
<tr>
<th>NEWS scores</th>
<th>Clinical risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Low</td>
</tr>
<tr>
<td>Aggregate 1-4</td>
<td>Medium</td>
</tr>
<tr>
<td>RED score (Individual parameter scoring 3)</td>
<td>Medium</td>
</tr>
<tr>
<td>Aggregate 5-6</td>
<td>High</td>
</tr>
<tr>
<td>Aggregate 7 or more</td>
<td>High</td>
</tr>
</tbody>
</table>
Any other primary care:
PEFR and start PEFR chart.
FBC, U&Es.
Sputum and blood cultures.
12 lead ECG.

<table>
<thead>
<tr>
<th>Age</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior History of patient’s therapy</td>
<td>Reaction or allergy to some specific medicines</td>
</tr>
</tbody>
</table>

For differential diagnosis following assessment tools are considered:

**Perfusion status assessment:** The ability of the cardiovascular system to provide tissues with an adequate oxygenated blood supply to meet their functional demands at that time and to effectively remove the associated metabolic waste products is called perfusion. Perfusion assessment results in adequate, Borderline, Inadequate, Extremely poor and NO perfusion status based on the certain visually observable parameters.

**Respiratory status assessment:** The respiratory status gives the indication about the breathing pattern and breathing capability of patient. Respiratory status assessment gives Normal, Mild, Moderate and Severe distress based on some visually observable and measured physiological parameters.

**Conscious state assessment (GCS Score):** The GCS is an objective measure of consciousness. The score should not be estimated. The principal in each category of the GCS is that the patient should receive the highest score in that category based on their response. The application of painful stimuli should be performed in a professional manner as part of a clinical assessment. Painful stimuli should not be repeatedly applied to a patient if the expected response is not elicited.

**vi) Design Model**

This model maps the conceptual analysis made explicit in the knowledge and communication models to a specific implementation. The model specifies the target software and hardware platform, the various software modules included in the target system, their functional and technical specifications and the mapping between these modules and the conceptual components identified during the analysis phase.

After acquiring knowledge from the experts and developing the different models of commonKADS framework, it needs to be design ontology using protégé software.
2) Risk level stratification based on early warning scoring system

Early warning scoring systems are developed to facilitate the assessment of patient’s condition based on minimal set of medical parameters. There are various systems available proposed by different researcher. NEWS system is one of the most efficient ED-based EWS. Risk level stratification based on the score of individual patients is the key criterion for using this system for mentioned purpose. NEWS needs patients most commonly monitored body vitals and score based on predefined values. Aggregate score indicates the severity of patient’s criticality of illness. This table is used for creating emergency health care ontology.

3) Creating Emergency Medicine Ontology using Protégé

Ontologies are essential component of the semantic web. It provides a shared a common vocabulary to support the sharing and reuse of knowledge. Protégé is free, open-source ontology editor and a knowledge management system. It provides a graphic user interface to define ontologies. It supports ontology creation, visualization and manipulation in various formats. This segment defines the development of Risk level ontology that is a knowledgebase for the given expert system and is used for querying on user’s request.

![Figure 3. Classes view of created ontology in Protégé](image)
4) **Block diagram of Meditrace**

The architecture of this proposed system is based on the client-server technology following MVC architecture. The architecture has different sections: the client layer, the application logic level (JSP), the semantic web framework (JENA) and database layer. The client layer initiates request by accessing the front end designed for a web browser through JSP technology. This request is being served by server running on machine where the controller is designed to serve the desired task using servlets. Ontology is created by protégé, an open source ontology editor developed by Stanford University, for storing the knowledge base. OWL file is stored in either local directory or it can be available online for assessing the ontology from anywhere across the web through JENA API for inferring the effective information. JENA is a java framework for building semantic web application. It provides programming environment for RDF, RDFS, and OWL. The RDF is used for encoding the information about web resources as well as information about and relations between things in the real world. OWL is an ontology web language used for knowledge representation. OWL facilitates machine interpretability of web content to a greater extent than that supported by XML or RDF. Additional information required to support the application is store in MYSQL database relating to user management, treatment guidelines, and disease information.

![Block diagram of Meditrace](image)

*Figure 4. Meditrace – Online Expert system for Emergency Medicine*
5) Meditrace – Online Expert system

Figure 4. Flowchart showing the entire flow of online expert system
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Figure 5. Screen for entering patient basic information and body vitals for score calculation

Figure 6. Screen for entering visually observable parameters differential diagnosis
g. Achievements with respect to objectives

- Performed the risk level stratification of patient based on physiological parameters frequently monitored as a part of ambulatory care in emergency medicine department. This score is derived from the risk level ontology stored on server side.
- Proposed system has suggested list of probable diseases based on the inputs from the EM-paramedic screed from the disease ontology stored on server side.
- The proposed system has also listed the steps of relevant treatment guidelines for the suggested disease.

Results:

![Pie chart showing Disease Prediction Probability with 75% Success and 25% Failure]
h. Conclusion

- This proposed system has performed the risk level stratification of patient at reasonably good level. The system found its applicability for training the EM-paramedic as well.
- The proposed system has suggested the probable disease list at reasonably accurate level. The treatment hierarchy is as per the EM-paramedic standard guideline followed by the primary health care provider.

i. Copies of papers published and a list of all publications arising from the thesis

Paper published in UGC approved journal


Paper submitted in UGC approved journal


j. References

1) Department of Veterans Affairs, Washington, "Early Warning Scores: A Systematic Review" in Jan 2014


3) Royal College of Physician "National Early Warning Score (NEWS)" Report in 2012.

4) North West Ambulance Service (NHS trust) "Paramedic pathfinder and community care pathways V3", 2014 s


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7) Uppanisakorn S., Bhurayanontachai R., Boonurat J., Kaewpradit J. "National Early Warning Score (NEWS) at ICU discharge can predict early clinical deterioration after ICU transfer


19) Yang D., Tong L., Ye Y., Wu H. “Applying CommonKADS and semantic web technologies to ontology-based E-government knowledge system”


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