https://doi.org/10.48047/AFJBS.6.5.2024.3410-3422

AfricanJournalofBiological Sciences

Ontology-Based Online Expert System for Emergency Medicine

Rutvik. K. Shukla*[1], Prakash. M. Pithadiya[2], Hardik V. Kannad[3], Vipul. C. Rajyaguru[4]

[1*]Assistant Professor, Instrumentation & Control Engineering Department, Government Engineering College, Mavdi-Kankot Road, Rajkot, Gujarat, INDIA,E-mail:rutvikshukla@gecrajkot.ac.in Orcid id:0000-0001-5223-8465
[2]Assistant Professor, Instrumentation & Control Engineering Department, Government Engineering College, Mavdi-Kankot Road, Rajkot, Gujarat, INDIA, E-mail:pmpithadiya@gecrajkot.ac.in
[3]Assistant Professor, Instrumentation & Control Engineering Department, Government Engineering College, Mavdi-Kankot Road, Rajkot, Gujarat, INDIA, E-mail:hvkannad@gecrajkot.ac.in
[4]Assistant Professor, Instrumentation & Control Engineering Department, Government Engineering College, Mavdi-Kankot Road, Rajkot, Gujarat, INDIA, E-mail: vcrajyaguru@gecrajkot.ac.in

Article History
Volume 6, Issue 5, Apr 2024
Received: 22 Apr 2024
Accepted: 29 Apr 2024
doi:***10.48047/AFJBS.6.5.2024.3410-3422***

Abstract

The manuscript includes the current health care status and role of ICT in medical field specifically in India. The system proposed in this manuscript is based on the knowledge based expert system. So, it also includes the classification of the expert system and applicability of expert system in medical field. Emergency medicine and the basic assessment tools which are needed as a part of pre-hospital medical care are also included in this manuscript. Ontology is the prime component in the semantic web. So, here the concept of ontology and how to make the ontology from the elicited knowledge-base is also included. The system proposed here utilizes the java-based client-server MVC architecture. JENA API is used for integration between knowledge-base stored in OWL format with JAVA servlet. The system takes the vital parameters for primary assessment of patient's condition from the EM paramedic from the client-side and passes this information to the server-side where the primary risk level stratification will be calculated by the ontology and score is available to the paramedic.

Keywords:Early Warning Scoring System (EWS), Emergency Department (ED) Ontology,Ontology web language (OWL), Expert System (ES), Protégé

1. Introduction

Emergency medicine is an essential part of health care system in every country, as it saves the people under acute conditions. The fundamental component includes rapid assessment, timely intervention, and immediate transport of the patient to the closest hospital. Most of the peoplesuffering from acute diseases often die due to the lack of accessible primary care. Additionally, primary care services in rural regions of developing countries, such as India, suffer from a shortage of adequately trained professionals.This constraint restricts the availability of adequate healthcare services for the entire population.The government continually endeavors to tackle and resolve these challenges by crafting new and advanced health policies. However, the implementation often faces hurdles due to inadequate infrastructure and a shortage of trained professionals in such a densely populated country.The prompt onset of primary treatment largely hinges on the expertise of paramedics and other medical personnel present in the ambulance.Assisting them is crucially important, requiring the provision of a decision-making system that enables them to prioritize patients based on risk levels and initiate treatment and transportation to the nearest healthcare facility.(Shukla and Bhatt, n.d.-b)

This decision-making system can broadly fall into two categories: Decision Support System (DSS) and Expert system (ES). A DSS is an interactive system designed to assist decision-makers in utilizing data and models to address unstructured or semi-structured problems.An ES is a problem-solving computer program specifically designed to excel in a specialized problem domain that demands specialized knowledge and skill, achieving notable performance. While both DSS and ES are geared towards facilitating the decision-making process, they differ slightly in their approaches and applications.ES can be further categorized into several types, with some of the most prominent ones being: Rule-based systems, Knowledge-based systems, Case-based systems, Agent-based systems, and Ontology-based systems. Expert systems find extensive application in healthcare, whether in predicting or diagnosing diseases. They prove particularly invaluable when medical professionals are unavailable.(Shukla and Bhatt, n.d.-a)

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

Background

A medical emergency is an unexpected wound or medical complaint (physiological or psychological) requiring immediate medical care. The primary objectives of emergency medical care are threefold: Firstly, to ensure the timely detection of a medical emergency, provide urgent First Aid, and administer efficient resuscitation. Secondly, to facilitate the prompt and safe transportation of the patient to the most appropriate emergency medical department within a hospital. And thirdly, to deliver subsequent definitive treatment as necessary.Thus, pre-hospital care is the most important area, every emergency medical personnel have to look for. Pre-hospital care should be simple, sustainable, and efficient. Paramedical personnel play a very important role in this using their dedicated and equipped vehicle. The paramedical team should comprise of: EMT basic, EMT Paramedic and EMT advance, with each one of them having dedicated roles and responsibilities (Sharma and Brandler 2014).

India is right now amidst a monetary and demographic transition. Since the country is facing a serious epidemiological transition due to urbanization with changing lifestyles, it results in a rapid expansion of cardiovascular and cerebrovascular illness, diabetic problems, Chronic Obstructive Pulmonary Disease (COPD), and so on. Moreover, communicable diseases (acute respiratory infections, acute diarrhoeal diseases, tuberculosis, malaria, etc.) keep on increasing considerable amount of burden of disease in the country. Other than these, some of the unintentional injuries (road traffic accidents, fires, falls, etc.) and intentional injuries (self-inflicted injuries and those due to violence) also represent a significant burden of disease in the nation. Many of these conditions require emergency care in their acute stages or are acute in nature (Myocardial Infarction (MI), acute hemorrhages) (Joshipura, Hyder, and Rehmani 2004).

Our understanding of the goals of healthcare gives rise to the concept of "quality of health care." The main objectives of any medicinal service include health improvement of the population, sensitization towards people’s needs, and financial protection against ill-health expenses (“The World Health Report 2000.Health Systems: Improving Performance” 2000). India as a developing nation with large rural areas and populations has some crucial issues to deal with, such as prevent chronic infectious disease, the lack of adequately trained health care personnel and health care facilities, and a limited number of health care programs.

Telemedicine, a term that came into existence in the 1970s, means “healing at a distance”, signifies the usage of ICT to improve patient outcomes by increasing access to care and medical information. As per World Health Organization (WHO), 1998 “The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for the diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities (“The World Health Report 1998 - Life in the 21st Century: A Vision for All” 1998). As per the international telecommunication report (ITU) 1998, Telemedicine is potentially an efficient means of providing specialized medical services to a remote location. It has also stated that telemedicine promises to improve the quality of medical care and decreases cost, particularly in under-served urban and rural areas (Wright 1998). In 1998, a team of researchers from Biomedical Engineering Laboratory, Athens, Greece, has also explored the role of telemedicine in pre-hospital patient care and management using wireless technology in Ambulance (Pavlopoulos et al. 1998). This system is the stepping stone towards the discovery of ICT application in the emergency health care system.

Karlsten and Sjoqvist(Karlsten and Sjoqvist 2000)have suggested the usage of telemedicine and decision support in the emergency ambulance (pre-hospital). Early diagnosis in the ambulance itself can improve the handling of the patient at the hospital and can save the patient by initiating proper and timely treatment. This is also the first system to incorporate the use of a Decision Support System (DSS) in pre-hospital emergency care. The research proposed by Pavlopoulos and team in the year 1998, taken further by again the team of researcher from biomedical engineering laboratory in the year 2003 under the supervision of Kyriacou (Kyriacou et al. 2003). They have developed multi-purpose healthcare telemedicine systems by establishing a communication link from a mobile network. This system includes the scope of transmitting live data as well, but still, the system faces technological constraints in terms of feasibility as it transfers waveform and images.

Health information and quality authority report (2014), has also listed some of the prime usages of ICT in the national ambulance service. The report includes computer-aided dispatch – incident tracking system, emergency response resource location, incident address verification, satellite navigation systems used by emergency response personnel, communication between control centers and emergency response staff, mobile data terminals, and patient care report (“Review of Pre-Hospital Emergency Care Services to Ensure High Quality in the Assessment, Diagnosis, Clinical Management and Transporting of Acutely Ill Patients to Appropriate Healthcare Facilities.” 2014). Two of the senior researchers associated with the planning and development of healthcare solutions in Fujitsu Kyusu System have developed the project on information support solution in Emergency Medical Service proposing close collaboration between paramedics and medical institution (Sonoda and Ishibaei 2015).

Badr (Badr 2016)has examined the role of ICT in pre-hospital emergency medical services. Badr has also stressed on requirement of a specialized and unique type of intelligent transport system in emergency medical services. It was also suggested that ICT usage as telemedicine had a positive impact on emergency pre-hospital medical care. The smart ambulance system is another attempt to identify the role of ICT in pre-hospital emergency care(Gupta et al. 2016). The system was implemented into client-server architecture to make it a small size application and keep the data available at a central location.

Koceska and the team from Macedonia in the year 2019, proposed the system of a mobile wireless monitoring system for pre-hospital emergency care (Koceska et al. 2019). This system has utilized wireless bio-sensors for monitoring the vital parameters of a patient and this data will be transferred and monitored by the paramedic available in the ambulance. This system displays real-time vital data measurement, historical trends of these parameters, Glasgow coma scale, and place of injury and also incorporates triage procedure. Essentially, this system can serve as a complementary tool in Emergency Medical Services (EMS), enabling seamless real-time monitoring of patients' vital signs wirelessly and facilitating on-scene triage.This system does the designated task efficiently but it lacks intelligence and assistance for taking a proper decision.

Expert System

An expert system is a computerized system or software program that captures the knowledge of human experts and uses this knowledge to solve the problem as the expert does. An expert system can be considered as an assistive system that helps to solve the problem in the absence of experts. These computer-based systems found their existence in various fields depending on the nature and extent of the problem. An expert system is the rule-based Artificial Intelligence application designed to solve the problem in the intended domain.ES offers an effective and adaptable solution for addressing a multitude of problems that remain unsolvable through conventional methods.

Expert systems in the medical field serve primarily for diagnosis, monitoring, tutoring, and therapeutic purposes. Diagnostic expert systems aid doctors in identifying potential diseases, with their most notable feature being rapid decision-making in diagnosis and the selection of appropriate treatment within a short timeframe.India, as a developing country with the second largest population on earth and randomly distributed population across the country, efficient health care delivery is the most critical issue. In addition to this, the unavailability of trained professionals and field experts, this issue becomes more critical. Expert systems can play a vital role in solving this problem to a certain extent. ES can work as an assistive system for untrained medical staff especially in emergency medicine, which required immediate and effective treatment to the patient. The expert systems in the medical field are also called Clinical Decision Support Systems (CDSS)(Miller et al. 1986; Saba, Al-Zahrani, and Rehman 2012).

EWS (Early Warning Scoring) System

Clinicians and researchers require a robust method for prediction in a critically ill patient. There are varieties of a scoring system developed for this purpose in the Intensive care unit (ICU), emergency department (ED), and pre-hospitalization (PH). The ED-based scoring system considers lesser parameters that are readily available from the patient, while the ICU scoring system includes more parameters that are generally available from a patient admitted to ICU. Pre-hospitalization based scoring system is also designed in line with the ED scoring system (Smith et al. 2014). The most widely used ICU based scoring system includes APACHE II and APACHE II. While ED-based scoring system includes: MEWS and NEWS. PHEWS is the early warning scoring system used as a part of prehospital emergency care.

National Early Warning Scoring (NEWS) System was developed by the royal college of a physician ("National Early Warning Score (NEWS)" 2019). The applicability of this system was evaluated in an Indian scenario by a group of researchers from the department of general medicine, Vishakhapatnam (Vanamali, Sumalatha, and Varma 2014). While developing the NEWS system, they consider seven parameters for calculating the score and ultimately to assess the patient's health status. These parameters include respiration rate, oxygen saturation, any supplemental oxygen, temperature, systolic blood pressure, heart rate and level of consciousness.

Primary assessment tools in the emergency health care system

The primary assessment of a patient is the most critical part of the emergency health care delivery system. The vital sign parameters of the patient should be monitored continuously during the transportation to the hospital through an ambulance. The frequency of monitoring vital signs mainly depends on the actual status of the patient. Another assessment is performed either by asking the question to patient or by observing the patient situation visually. These assessment tools help to determine the current situation of the patient and to predict the probable disease and ultimately help to decide the further course of treatment. This helps the EM-staff to initiate the proper treatment even before the patient reaches the hospital, which further increases the chances of a patient's survival ("Clinical Practice Guidelines" 2014).

Three most important primary assessment tools are: Perfusion Status Assessment, Respiratory Status Assessment and Conscious State Assessment (Glasgow Coma Scale) (Victoria 2018).

Ontology

The Semantic Web was conceptualized by Tim Berners-Lee and entails providing automated access to information by leveraging machine-processable data semantics.Additionally, the Semantic Web employs metadata heuristics to facilitate automated access to information.By incorporating domain theories, or ontologies, to elucidate the semantics of data, the web offers a wholly innovative approach to knowledge dissemination.It has the capacity to weave together the vast network of human knowledge while enabling machine processability.Ontologies have found extensive use in the field of computer science, particularly within the domain of the semantic web, to establish a comprehensive and machine-interpretable shared understanding(Berners-Lee et al. 2001).

Ontologies organize the domain semantics by stating their components; thus, they contain the concepts which defined the inner attributes of the stated concepts and the properties to describe their interrelationship. Ontologies are developed from the common vocabularies shared and agreed amongst the knowledge developers. These characteristics of the ontology make it suitable to utilize in various tasks of the diversified field of research (Maedche and Staab 2001). The ontology definition is given by Gruber(Gruber 1993) defined is as "a formal, explicit specification of a shared conceptualization".In this context, Gruber emphasized the formalization of concept specifications and their interrelationships, enabling the representation and sharing of knowledge among various agents. Guarino (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 (Corcho, Fernández-López, and Gómez-Pérez 2003; Gómez-Pérez and Corcho 2002; Liu and Zsu 2009). In ontology, knowledge can typically be described using five fundamental components: classes, instances, relations, functions, and axioms.

Ontology Languages

There are various formal languages available in computer science to create ontologies. These languages serve to encode knowledge within an ontology in the simplest, most formal, and human-understandable manner possible. These languages are declarative in nature, and their key advancements lie in their level of expressiveness and the capabilities of their inference engines. The classification of ontology languages can be done in two parts: (Corcho and Gómez-Pérez 2000) Traditional ontology language and web-based semantic ontology language. XOL (Ontology Exchange Language, SHOE (Simple HTML Ontology Extension), RDF (Resource Description Framework) ("RDF/XML Syntax Specification (Revised)," n.d.), RDF Schema, DAML-OIL, OWL (Ontology Web Language) ("OWL Web Ontology Language Guide," n.d.) are some of the well-known examples of web-based semantic ontology languages.

2. Implementation of Proposed System

Overall System Architecture

The architecture of this system is built upon client-server technology, adhering to the Model-View-Controller (MVC) architecture. According to Figure 1, the architecture comprises distinct sections: the client layer, the application logic level (JSP), the semantic web framework (JENA), and the database layer. The client layer initiates a request by accessing the front end designed for a web browser through JSP technology. This request is being served by a server running on a 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 functions as a Java framework tailored for the development of semantic web applications.It furnishes a programming environment tailored for RDF, RDFS, and OWL. The application relies on the MYSQL database to store additional information crucial for its operation, including data pertaining to user management, treatment guidelines, and disease information.

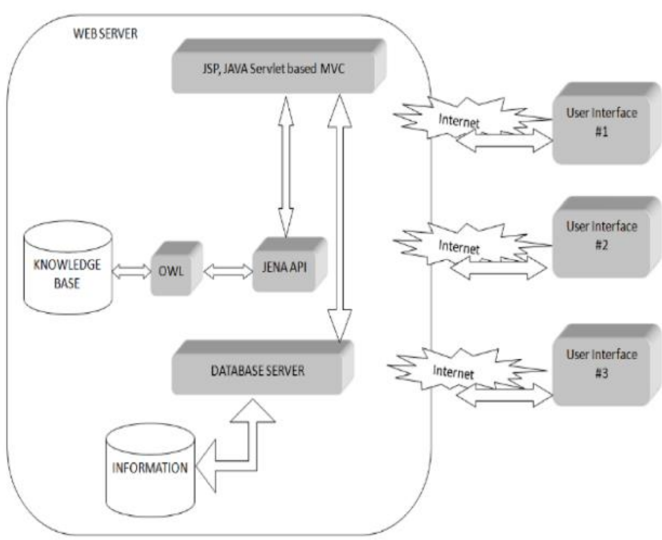

Figure 1. Architectural framework of the developed system

Ontology Development Phase

In this developed expert system, it incorporates NEWS based scoring system for risk level stratification and various primary assessment tools for differential diagnosis purpose in emergency health care service. Protégé is used to develop the ontology for emergency medical purposes. Ontology is developed by the knowledge extracted from the knowledge providers in the emergency medicine sector.

Step-1. Define class and class hierarchy

This is the first and most important step in developing an ontology. Initially, a patient class is created with the relevant characteristics of the patient as its subclass. The risk level ontology includes another class as a vital sign and under that few subclasses included i.e. body temperature, heart rate, respiration rate, etc.

Step-2. Define Object and Datatype property

Property is used to define a binary relationship between individuals or between individuals to the XML data type. OWL has two main types of properties: First is an object property, which gives a relationship between individuals from two classes. The second is the datatype property, which is used to assign the relationship between an individual to a data value. This developed ontology contains several data and object properties. Object properties are used to relate to individuals. For instance, the Patient is related to PatientID through object property called "hasID". Every patient has a specific vital sign indication related to object property "hasVitalSign". The data type properties are used to assign a specific data type to individuals. While the patient has PatientID which has ID in integer format defined through data type property called "hasDID". The patient class has a specific gender in String form related through data property called "hasGender".

Step-3 Defining facet, range, and domain of the property

Facets are characteristic of property which is used to put a certain restriction on property value and value type of property. In addition to this, the property also has a range and domain. For a given case, Object property hasPulse1 has a domain of Perfusion_Status and range extended to a class Pulse. Similarly, hasVitalSign has a domain Patient and range as a class VitalSign.

Step-4 Creating Individuals

Individuals are the concrete object of classes. These instances were created in the protégé tool. These individuals are used to form a rule-based on provided range values/symptoms or disease to the user.

Web based system - THE MEDITRACE

EM registration & login page

This page is used to enter all the basic information on emergency staff. This screen generates a login for that paramedic. The system also demands the name of the hospital and the unique ID number provided by the hospital. This stores the email id of the patient as login and the default password will be given to that person. The login page is designed to access the system through already assigned or generated login credentials. With the help of this screen, EM-staff, as well as Admin, can access the system and its functionalities.

Emergency Risk Level Assessment & Risk level score

This screen is designed to take appropriate input from paramedic staff. This page includes two sections. The first section is designed to take basic information of the patient including name, age, and gender. The second section demands information about the values of physiological parameters. The risk display screen is used to display the Risk assessment score and its level as shown in Figure 2. This page will fetch the result from the knowledge-base based on the inputs provided earlier by the paramedic staff. This screen has the selection on the bottom section, where EM-staff can decide whether to go for differential diagnosis or to transport the patient to the nearest hospital.

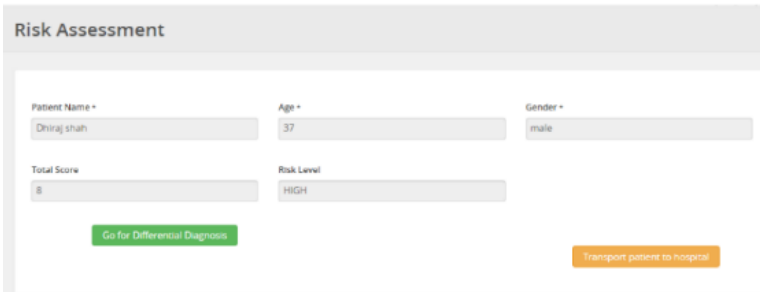

Figure 2: Risk assessment score page

Differential Diagnosis

This screen is used to get additional input from the paramedic staff. This page is divided into three main sections. As per Figure 3, the first section is for perfusion assessment, which takes a few visually observable inputs along with values of the physiological parameter. While the second section includes respiratory assessment, it asks additional visually observable parameters along with the value of few vital sign parameters. The third section demands additional information for GCS score calculation and consciousness assessment.

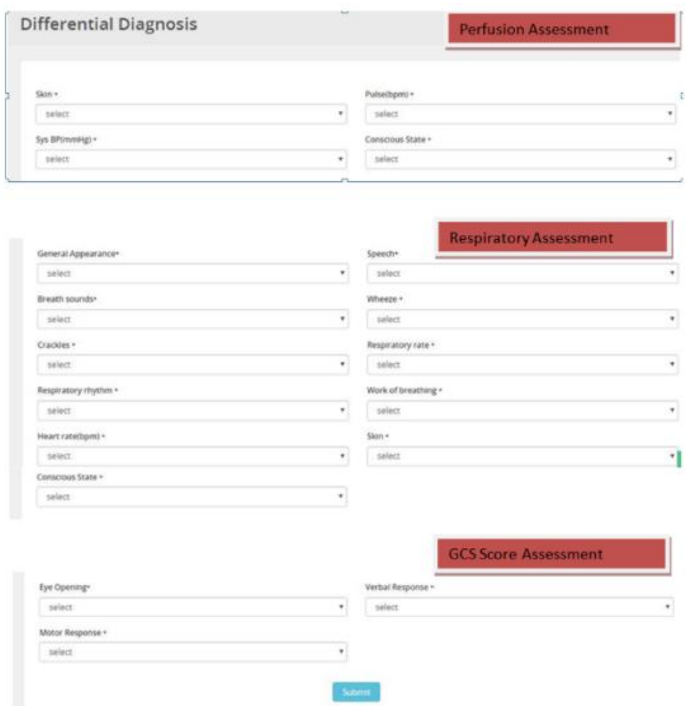

Figure 3: Differential diagnosis assessment screen

Primary Assessment Result screen

This is the display screen designed to display primary assessment results and a list of probable diseases. As shown in Figure 4, this page includes the status of perfusion, respiratory, and GCS score. This page also displays suggested disease and seeks the paramedic's input on whether to go for treatment or transport the patient to the nearest hospital.

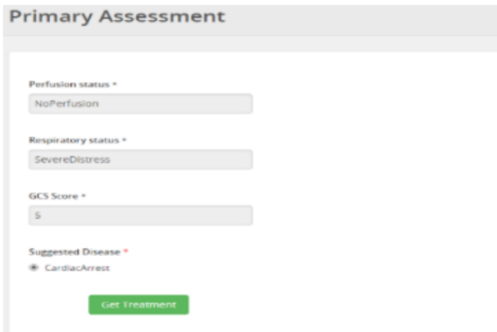

Figure 4: Assessment result screen

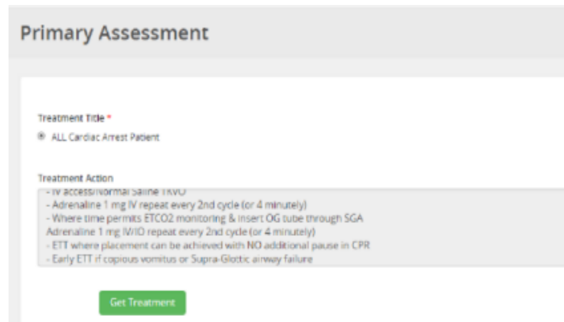

Figure 5. Treatment screen step-1

Treatment

This page is designed to fetch the treatment chart for the particular disease. This process follows a sequence of titles and actions. The treatment may include single or more than one step as shown in Figure 5. Depending upon the response of the patient to a given treatment, the paramedic needs to select an appropriate option. Accordingly, the treatment chart displays the next step of treatment. The last page of the treatment asks the paramedic for selecting the option about whether the treatment has been applied as per the suggestion or not. On every screen, there is an option for transporting the patient to the hospital by leaving further steps of treatment.

3. Results and Discussion

Testing Dataset

The proposed system was tested and evaluated on localhost using an apache tomcat server. As for finding the effectiveness of this system, it needs to be tested with the actual patient database. Shree Giriraj Multispecialty Hospital is one of the well-known hospitals located in Rajkot city. This hospital has specialization in critical care with a team of energetic and experienced medical professionals. The developed system was tested with the database provided by the Giriraj hospital. For effective testing of the proposed system, the process of selecting the database is very crucial. Hence, the data collection is mainly concentrated into the Emergency Department only. The database is selected considering all possibilities and variations. This includes gender, age variation (Adults), and patients with a past medical history. To check the efficacy of the system and to check its validity in a clinical environment, it is necessary to cover all possibilities that arise in the emergency health.

Validation Results

As per the chart shown in Figure 6, the collected patient database from the hospital is given to Meditrace and their results are stored in the system. The analysis of this result shows that more than 50 patients are having low scores and the rest of the 50 patients having scored in either medium or a higher range. In high-risk patients, the majority of cases required immediate intervention by the paramedic staff. Majority of the patient died during their in-hospital treatment, The NEWS score of those patients is more than 10. This indicates that the NEWS score of an individual patient states the potential risk to an individual's life.

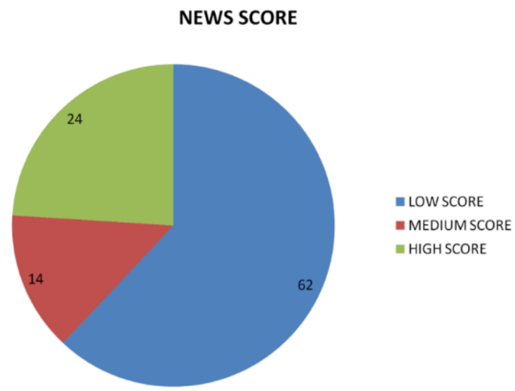

Figure 6. Patients NEWS score and its range variation

Figure 7 indicates patient percentage with a cardiac emergency. The patient database of around 27% includes a score of more than 7, while 27% data includes patients with a medium score, while the rest of 45% of patients are having a low score. This wide variety of scoring and having various diseases serves as valuable data for the validation of the Meditrace system. While Figure 8 reveals the percentage of a patient with a respiratory emergency. This chart shows patients with more than 7 scores are on the higher side of the population. While patients have scored in the medium and lower range are sharing 30 percent of the total population. With these various possible input databases, the Meditrace system was tested and validated. The Risk level stratification performed by the Meditrace based on the calculated total score is proven to be very effective and accurate for time-critical cases.

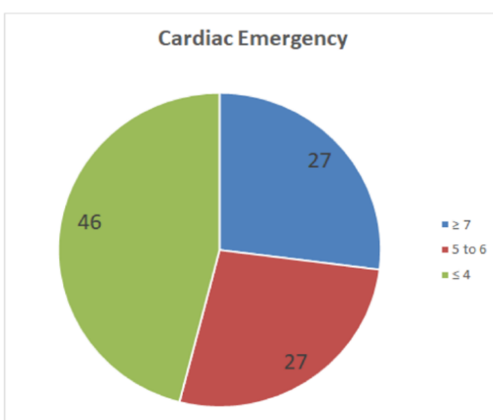

Figure 7. Patient database with cardiac emergency variation

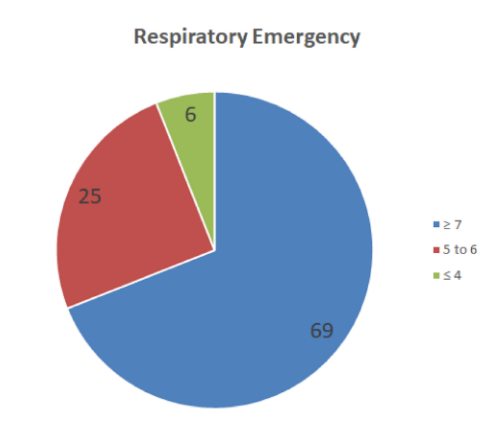

Figure 8. Patient database with respiratory emergency

As depicted from Figure 9, when this database is utilized for validating the system, its disease prediction probability shows a success rate of around 75%. This means the developed system is capable of forecasting the probable disease with an accuracy of around 75%. This indicates its effectiveness and usefulness of the system in the emergency health care scenario for assisting paramedics. While as per Figure 10, It shows the success rate of individual diseases as per the patient database used for the validation purpose. For some of the diseases, the system has proven to be 100% accurate with precise disease forecasting proficiency.While for the rest of the diseases the accuracy of the system varies from 20% to 80%.

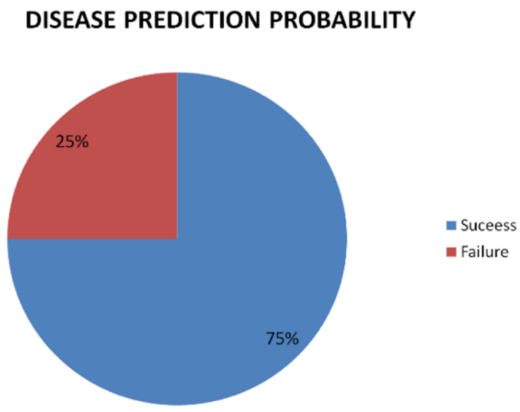

Figure 9. Disease prediction probability

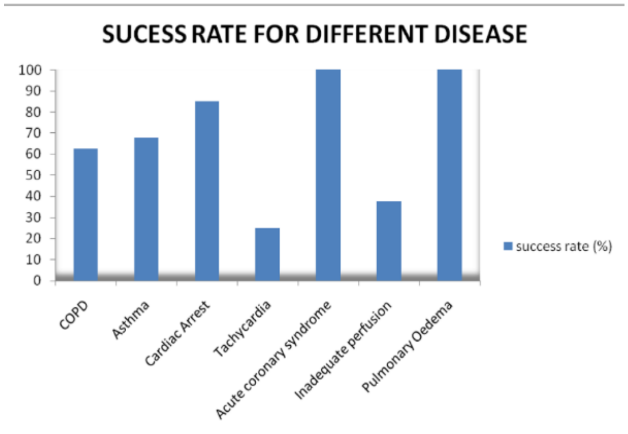

Figure 10. The success rate for different diseases

4. Conclusion

The Meditrace system is developed for assisting the paramedic staff in case of emergency health care sector in the absence of an expert medical professional. This web-based system is developed for risk level stratification, differential diagnosis, and treatment procedure. Risk level stratification is performed by a well-designed and widely accepted scoring system. This NEWS scoring system categorizes the risk level of patients based on the aggregate score calculated from the individual score of most frequently monitored physiological parameters. NEWS scoring system is designed to serve effectively in emergency medicine. In the Indian scenario, the effectiveness of this scoring system is reasonably acceptable. The results are also replicating the same phenomenon, indicating higher the score higher the risk to an individual's health. On the other hand, differential diagnosis task is performed by various patient assessment tools. These tools are accessing the patient's condition based on some visually observable symptoms along with few physiological parameters. The results achieved from the patient assessment tools are used by the rules defined for differential diagnosis purposes. The outcome of this developed system is the list of probable disease along with an option to choose the most appropriate one. Both of these tasks are performed by the ontologies designed and developed by extracting the knowledge from the domain experts. The system also offers a treatment suggestion for a specific disease. This facility is incorporated in the developed system by considering the existing emergency guidelines available and accepted by the EM community. This makes the system to be helpful while providing training to EM-staff.

The development of an expert system from a semantic web-based ontological framework is one of the key aspects of Meditrace. Ontologies are used in the semantic web domain for getting information in a comprehensive and machine-understandable format. Ontologies are generic, reusable, and can be shared between people. This architecture enables the system to build its knowledge base using available ontology either stored locally or over the web. This architecture allows the domain expert to maintain the knowledge base in the ontology without making any changes in the overall system. This is the modular approach accepted for developing the expert system which makes the system scalable.

Acknowledgement

We gratefully acknowledge Shree Giriraj Multispecialty Hospital, Rajkot, Gujarat, INDIA., for generously providing access to the patient data essential for this research. Their cooperation was instrumental in the success of this study. We also extend our appreciation to Dr. Vishal Sadadiya, Emergency Medicine Department for their invaluable assistance during data collection.

Conflict of Interest

The authors have declared that there are no conflicts of interest regarding the publication of this work.

References

Badr, Nabil Georges. 2016. “Could ICT Be Harnessed for Prehospital Emergency Medical Services?” In *Proceedings of the International Joint Conference on Biomedical Engineering Systems and Technologies*, 269–76. SCITEPRESS-Science and Technology Publications, Lda.

Berners-Lee, Tim, James Hendler, Ora Lassila, and others. 2001. “The Semantic Web.” *Scientific American* 284 (5): 28–37.

“Clinical Practice Guidelines.” 2014. Fifth Edition. Ireland: Pre-hospital emergency care council.

Corcho, Oscar, Mariano Fernández-López, and Asunción Gómez-Pérez. 2003. “Methodologies, Tools and Languages for Building Ontologies. Where Is Their Meeting Point?” *Data & Knowledge Engineering* 46 (1): 41–64.

Corcho, Oscar, and Asunción Gómez-Pérez. 2000. “A Roadmap to Ontology Specification Languages.” In *International Conference on Knowledge Engineering and Knowledge Management*, 80–96. Springer.

Gómez-Pérez, Asunción, and Oscar Corcho. 2002. “Ontology Languages for the Semantic Web.” *IEEE Intelligent Systems* 17 (1): 54–60.

Gruber, Thomas R. 1993. “A Translation Approach to Portable Ontology Specifications.” *Knowl. Acquis.* 5 (2): 199–220. https://doi.org/10.1006/knac.1993.1008.

Guarino, N. 1998. *Formal Ontology in Information Systems: Proceedings of the 1st International Conference June 6-8, 1998, Trento, Italy*. 1st ed. Amsterdam, The Netherlands, The Netherlands: IOS Press.

Gupta, Poonam, Satyasheel Pol, Dharmanath Rahatekar, and Avanti Patil. 2016. “Smart Ambulance System.” *International Journal of Computer Applications* 6: 23–26.

Joshipura, Manjul, Adnan A Hyder, and Riffat Rehmani. 2004. “Emergency Care in South Asia: Challenges and Opportunities.” *Journal of the College of Physicians and Surgeons–Pakistan: JCPSP* 14 (12): 731–35.

Karlsten, Rolf, and BA Sjoqvist. 2000. “Telemedicine and Decision Support in Emergency Ambulances in Uppsala.” *Journal of Telemedicine and Telecare* 6 (1): 1–7.

Koceska, Natasa, Radko Komadina, Monika Simjanoska, Bojana Koteska, Andrej Strahovnik, Anton Jošt, Ana Madevska-Bogdanova, et al. 2019. “Mobile Wireless Monitoring System for Prehospital Emergency Care.” *European Journal of Trauma and Emergency Surgery*, 1–8.

Kyriacou, Efthyvoulos, S Pavlopoulos, Alexander Berler, Marios Neophytou, Athena Bourka, Angelos Georgoulas, Anthoula Anagnostaki, et al. 2003. "Multi-Purpose HealthCare Telemedicine Systems with Mobile Communication Link Support." *Biomedical Engineering Online* 2 (1): 7.

Liu, Ling, and M. Tamer Zsu. 2009. *Encyclopedia of Database Systems*. 1st ed. Springer Publishing Company, Incorporated.

Maedche, Alexander, and Steffen Staab. 2001. "Ontology Learning for the Semantic Web." *IEEE Intelligent Systems* 16 (2): 72–79.

Miller, Randolph A, Melissa A McNeil, Sue M Challinor, Fred E Masarie Jr, and Jack D Myers. 1986. "The INTERNIST-1/Quick Medical REFERENCE Project—Status Report." *Western Journal of Medicine* 145 (6): 816.

"National Early Warning Score (NEWS)." 2019. Standardising the Assessment of Acute-Illness Severity in the NHS. London.

"OWL Web Ontology Language Guide." n.d. Accessed June 11, 2019. https://www.w3.org/TR/owl-guide/.

Pavlopoulos, Sotiris, Efthyvoulos Kyriacou, Alexandros Berler, Spiridon Dembeyiotis, and Dimitrios Koutsouris. 1998. "A Novel Emergency Telemedicine System Based on Wireless Communication Technology-AMBULANCE." *IEEE Transactions on Information Technology in Biomedicine* 2 (4): 261–67.

"RDF/XML Syntax Specification (Revised)." n.d. Accessed June 11, 2019. https://www.w3.org/TR/REC-rdf-syntax/.

"Review of Pre-Hospital Emergency Care Services to Ensure High Quality in the Assessment, Diagnosis, Clinical Management and Transporting of Acutely Ill Patients to Appropriate Healthcare Facilities." 2014. Dublin: Health Information and Quality Authority. https://www.hiqa.ie.

Saba, Tanzila, Saleh Al-Zahrani, and Amjad Rehman. 2012. "Expert System for Offline Clinical Guidelines and Treatment." *Life Sci J* 9 (4): 2639–58.

Sharma, Mohit, and Ethan S Brandler. 2014. "Emergency Medical Services in India: The Present and Future." *Prehospital and Disaster Medicine* 29 (3): 307–10.

Shukla, Rutvik, and Dr. Chetan Bhatt. n.d.-a. "COMMONKADS MODEL FRAMEWORK FOR WEB-BASED EMERGENCYMEDICINE DECISION SUPPORT SYSTEM." *GLOBAL JOURNAL OFENGINEERING SCIENCE AND RESEARCHES* 5 (9): 306–12. https://doi.org/10.5281/zenodo.1441322.

———. n.d.-b. "EMERGENCY HEALTH CARE ONTOLOGY FOR RISK LEVEL DETECTION." *International Journal of Emerging Technologies and Innovative Research (Www.Jetir.Org)* 6 (5): 472–78. http://doi.one/10.1729/Journal.20886.

Smith, ME Beth, Joseph C Chiovaro, Maya O'neil, Devan Kansagara, Ana R Quiñones, Michele Freeman, Makalapua L Motu'apuaka, and Christopher G Slatore. 2014. "Early Warning System Scores for Clinical Deterioration in Hospitalized Patients: A Systematic Review." *Annals of the American Thoracic Society* 11 (9): 1454–65.

Sonoda, Takeharu, and K Ishibaei. 2015. "Project on Information-Support Solution in Emergency Medical Services." *Fujitsu Sci Technol J* 51: 39–49.

"The World Health Report 1998 - Life in the 21st Century: A Vision for All." 1998. Geneva: WHO World Health Organization (WHO).

"The World Health Report 2000.Health Systems: Improving Performance." 2000. Geneva: WHO World Health Organization (WHO).

Vanamali, DR, N Sumalatha, and Sriharsha Varma. 2014. "The Role of National Early Warning Score (NEWS) in Medical Emergency–Patients in Indian Scenario: A Prospective Observational Study." *Journal of Evolution of Medical and Dental Sciences* 3 (13): 3524–29.

Victoria, Ambulance. 2018. *Ambulance Victoria Clinical Practice Guidelines for Ambulance and MICA Paramedics*. Ambulance Victoria.

Wright, David. 1998. "Telemedicine and Developing Countries. A Report of Study Group 2 of the ITU Development Sector." *Journal of Telemedicine and Telecare* 4: 1–85.