A Proposal of a Comprehensive Medical Emergency Decision Support System

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Abstract - *The aim of pre-hospital emergency medicine is to save lives, minimize sanitary harm and restore the quality of life as good as possible. Emergency pre-hospital care has the challenge of being time critical in nature. It requires rapid decision making despite the limited information around the patient which contributes to the high risk of medical errors. Although many clinical decision systems have been proposed many decades ago for the purpose of improving the quality of healthcare and reducing medical errors in clinics and emergency departments, but none of them had introduced a design of a decision support system for the pre-hospital emergency treatment. This paper introduces a high level design for a comprehensive medical emergency decision support system (CMEDSS). The major contribution of this paper is that it provides a framework for a medical emergency decision support system that addresses the challenges of pre-hospital emergency treatment through the use of the patient's electronic health record (EHR) and artificial intelligence techniques during the decision making process*.

Keywords: Emergency expert system; Intelligent decision support system; Electronic health record; Pre-hospital and emergency treatment.

1 Introduction

The aim of emergency medicine is to save lives, minimize sanitary harm and restore the quality of life as best as possible. Pre-hospital care has the challenge of being time critical in nature.

The literature has posted the potential role of health information technology in reducing emergency medical response times [1, 2] and improving the level and type of care provided to a patient through emergency care [3, 4, 5].

Indeed, next generation medical emergency systems have been identified as an essential component of healthcare systems that should enable decision support for an integrated voice and data emergency communications system [6]. To this aim, the Hatfield Report [7] provided recommendations toward upgrading medical emergency systems infrastructures so that they can sufficiently address improvements and opportunities made available by existing technologies such as Internet Protocol (IP) networking standards, voice over IP (VOIP) communications, location identification techniques and public safety answering point (PSAP) processes and resources [8].

A systematic literature review by Garg et al. [9] of 100 studies concluded that "Clinical decision support systems improved practitioner performance in 64% of the studies and improved patient outcomes in 13% of the studies". Another literature systematic review of 70 studies by Kawamoto et al. [10] found that "Decision support systems significantly improved clinical practice in 68% of trials."

Clinical decision support (CDS) systems, with the potential to minimize practice variation and improve patient care, have begun to surface throughout the healthcare industry. Clinical Decision Support Systems are "active knowledge systems which use two or more items of patient data to generate case-specific advice" [11]. This implies that a CDSS is simply a DSS that is focused on using knowledge management in such a way to achieve clinical advice for patient care based on some number of items of patient data. CDSSs are aimed at supporting clinical diagnosis and treatment plan processes; and promoting use of best practices [12].

This paper presents a high level design for a Comprehensive Medical Emergency Decision Support System (CMEDSS) based on artificial intelligence that takes into consideration the patient's electronic health record in order to improve the quality of the decision making process in terms of both speed and accuracy.

The use of the patient's electronic health record in the medical emergency decision making process is very important. It has been reported in [15] through a systematic review with healthcare practitioners how having preexisting patient information (e.g., medications, pre-existing medical conditions, allergies, blood type, etc.) could significantly reduce data collection time and help to reduce medical errors and to increase quality of care provision across the emergency response continuum of care.

Furthermore, the CMEDSS is designed in a way that permits the countries that didn't yet implement the concept of electronic health record (EHR) in their national healthcare centers to use the CMEDSS. This is because the decisions it makes don't totally depend on the patient's EHR, rather they are based on both the patient's EHR and his current status. So the CMEDSS can still function in the absence of the EHR.

The CMEDSS is proposed for emergency care ambulances and emergency departments where more accurate decisions are needed in critical time.

The paper is organized as follows: Section 2 provides a literature review on the related work on emergency medical DSSs. Section 3 provides an overview on the framework of the proposed CMEDSS. Section 3 discusses the process of the CMEDSS. And section 5 discusses the architecture and the components of the CMEDSS. Finally section 6 concludes the paper.

2 Related Work

Although medical decision support systems have been discussed extensively in the research, but researches introducing this technology into the area of medical emergency are too rare. We can summarize the researches that had introduced this technology to the area of emergency medicine below.

The first medical emergency decision support system was MEDAS - Medical Emergency Decision Assistant System, which was designed in 1980. MEDAS is a knowledge-based interactive diagnostic system which assists in diagnosis of multiple disorders in human body [13]. The knowledge base consists of disorder patterns that constitute the background medical information required for diagnosis in the emergency and critical care medicine. This system is designed to provide the clinician with decision aids from the time the patient is first seen in the emergency department until the immediate risk of life has been minimized. The system includes life support protocols, diagnosis, recommendations for data acquisition, guidelines for therapy, storage and retrieval of the patient record, and a consultant library that may be accessed in real time. An automatic knowledge acquisition system for MEDAS has been proposed in [14] which assist physicians to build, test, and verify the knowledge base for MEDAS without the involvement of knowledge engineer.

In [15, 16, and 17] a prototype has been made for a decision support system for medical Triage. Triage has been defined as the process of categorization of casualties based on their need for medical attention [16, 17]. In medical triage, the treatment category determines the level of urgency of medical attention, and decisions based on nurse's primary observations must be produced in the shortest time possible. In emergency departments in Australia, the triage nurses use the Australian Triage Scale (ATS) to guide them through the triage decision-making process [18]. The Australian College of Emergency Medicine (ACEM) adopts the Australian Triage Scale (ATS) as part of its triage policy [19]. Because the accuracy of triage decisions has a major impact on whether or not a patient may receive medical intervention in an appropriate time frame, it is critical for the health outcomes of the patient. It is envisaged that by providing decision support tools to assist triage nurses in producing correct and timely triage decisions that are consistent with standard triage scales, triage decision support systems can contribute to the improvement of quality of life of triage patients and also reduce costs occurring from misappropriation of resources [20].

The CMEDSS proposed in this paper combines the strengths of the medical emergency decision support systems discussed above in addition to the usage of patient's electronic health record (EHR) as an input to the DSS in emergency ambulances and departments, which is the major contribution of this paper.

3 The CMEDSS Framework

The CMEDSS is based on three aspects; intelligent decision support system, national electronic health records and web-enabled decision support system. The following subsections give an overview on each of them.

3.1 Intelligent Decision Support System (IDSS)

Decision making work is now becoming more 'knowledge oriented' [22] and the need for more 'knowledge-driven' decision making support has laid the foundation to many artificial intelligence approaches and furthered the development of Intelligent Decision Support Systems (IDSS) [15].

Intelligent Decision Support Systems (IDSS) is a term that describes decision support systems that make extensive use of artificial intelligence (AI) techniques. The aim of the AI techniques embedded in an intelligent decision support system is to enable these systems to support decision makers by gathering and analyzing evidence, identifying and diagnosing problems, proposing possible courses of action and evaluating the proposed actions to be performed by a computer, whilst emulating human capabilities as closely as possible [23].

These DSSs are person-computer systems with specialized problem-solving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems [24]. IDSSs have been called suggestion DSS [25] and knowledge-based DSS [26].

3.2 National Electronic Health Records (EHR)

With the national movement towards data interoperability and standards development, electronic health record concept is at the heart of health informatics. Its purpose can be understood as a complete record of patient encounters that allows the automation and streamlining of the workflow in health care settings and increases safety through evidence-based decision support, quality management, and outcomes reporting [27].

An electronic health record (EHR) is an evolving concept defined as a systematic collection of electronic health information about individual patients or populations [28]. Such records may include a whole range of data in comprehensive or summary form, including demographics, medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, personal stats like age and weight, and billing information. [27].

The need for a better quality of service, unique identification of electronic health records, and efficient monitoring and administration requires a uniform and nation-wide organization for service and data access [29]. Several healthcare organizations worldwide are moving toward nationwide implementation of interoperable electronic health records. For instance, Canada Health Infoway [30] is an organization that provides specifications for a standard and nationwide healthcare infrastructure. The goal is to integrate information systems from different health providers and administrations (e.g., hospitals, laboratories, pharmacies, physicians, and government agencies) within each province, and then connect them to a nationwide healthcare network with standard data formats, communication protocols, and a unique health history file for each patient; where the health information is accessible ubiquitously, using common services according to different access privileges for patients and providers. Infoway’s mission is to foster and accelerate the development and adoption of an interoperable Electronic Health Record (EHR) system [30].

National EHRs need a unique identifier for each record such as a national health record number which can be used to retrieve the patient's EHR.

3.3 Web-Enabled Decision Support System

Web services promote software portability and reusability in applications that operate over the Internet. They are a transition to service oriented, component-based, distributed applications. In other words, web services are applications implemented as Web based components with well-defined interfaces, which offer certain functionality to clients via the Internet [31].

Web-enabled DSSs are based on web services where users can access them through the Internet. All types of DSS can be deployed using Web technologies and can become Web-based DSSs. Figure 1 shows the interaction between the user and the decision support system through web services.

Figure 1. Web-enabled DSS

Web service architecture is built on open standards and vendor-neutral specifications i.e. they can be implemented in any programming language, deployed and then executed on any operating system or software platform [31].

4 The CMEDSS Process

The eventual network for EHR transactions is likely to be conducted over the World Wide Web, which is open, flexible and convenient [32]. For the purpose of being able to retrieve EHRs in mobility (i.e. in healthcare ambulance) and to centralize all the data and operations in one place and to reduce the load on client side (i.e. using thin clients), client-server architecture is the appropriate architecture for the proposed CMEDSS.

The CMEDSS is web-based which will be built on the server side of client-server architecture. The server side is located at a national healthcare center built around a country or several countries and keeps national EHRs for all people in that country.

At the server side, three-layer design is an effective approach to the development of robust and easy maintainable systems. This architecture is appropriate for CMEDSS that needs to support multiple user interfaces. The set of layers at the server side includes the following:

- Data layer - that manages stored data, usually in one or more databases. The data include EHRs and the knowledge base of the CMEDSS.

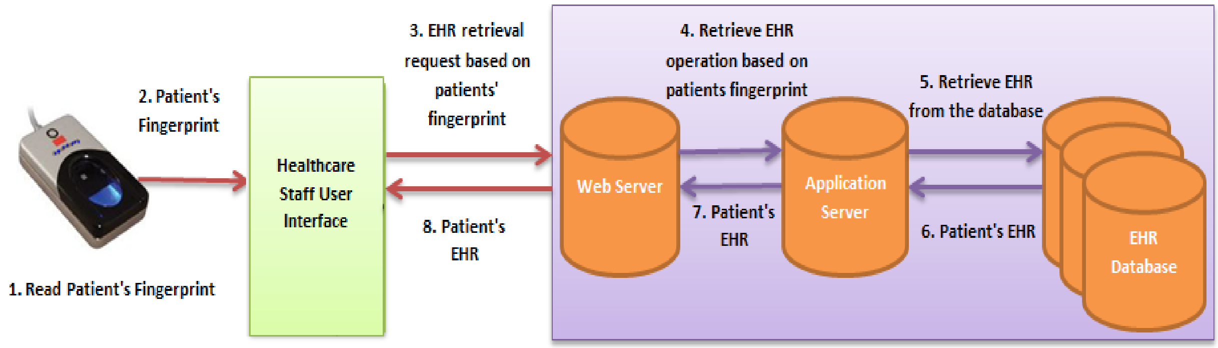

Figure 2. Real-time retrieval process of electronic health record based on the patient's fingerprint

- Business logic - (domain) layer that implements the rules and procedures of the business processing. It also includes the CMEDSS inference engine and the associated manipulation modules.

- View layer - that accepts input and formats and displays processing results.

As stated earlier, the national EHR needs a unique identifier. Using a national health record number to retrieve a patient's EHR is not suitable in emergency cases and especially in emergency ambulance care because the physicians have no means to know the patient's national health record number without being told. A better approach is to associate the patient's fingerprint with the EHR, so that in emergency cases, the patient's EHR can be retrieved easily by reading the patient's fingerprint using a fingerprint reader devise.

Figure 2 shows the real time retrieval process of EHR. First, the healthcare staff uses a fingerprint reader devise to read the patient's fingerprint. The patient's fingerprint is then entered into the emergency care (ambulance or department) computer. It is then used to retrieve the patient's EHR. The EHR is usually large and needs long time to be transferred to the emergency care computer; therefore a summary of the EHR can be requested to be transferred instead. The summary can be designed to include the standard and most important information about the patient (e.g., pre-existing medical conditions, allergies, blood type, etc.).

The CMEDSS core decision making processes have not been discussed yet. Figure 3 depicts the process of the CMEDSS. In order to get a decision from the CMEDSS, the physician inputs the patient's fingerprint and his current condition information into the physician user interface, and then submits this information to the server requesting a decision support.

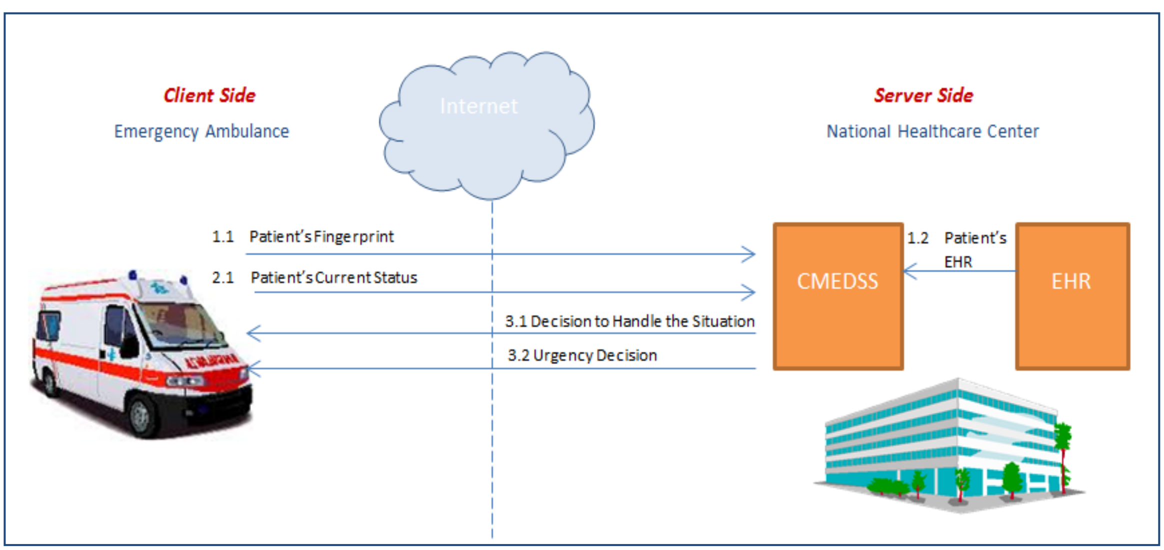

Figure 3. The CMEDSS Process

The server directs the request to the CMEDSS which is implemented internally at the server side. The CMEDSS retrieves the patient's EHR based on his fingerprint, extracts the important information from it, and use this extracted information along with the patient's current status information to output a decision regarding the patient's urgency level and a decision to handle the situation. The patient's urgency level determination is important in order to achieve an efficient appropriation of resources when the patient reaches an emergency department and improve the quality of care provided to the patient as recommended in [15, 16, and 17]. And the decision to handle the situation can assist physicians regarding the diagnosis in the emergency, critical care medicine, and pre-hospital treatment as proposed in [13]. The server then sends the CMEDSS output to the emergency physician user interface.

These operations will be highlighted in the following section which explains the structure and components of the CMEDSS and the responsibility of each component.

5 The Design of the CMEDSS

The design of the proposed CMEDSS is shown in Figure 4. The system has five components; the healthcare emergency staff user interface, the input module, the facts workspace, the inference engine and the knowledge base. These components are explained in detail in the following subsections.

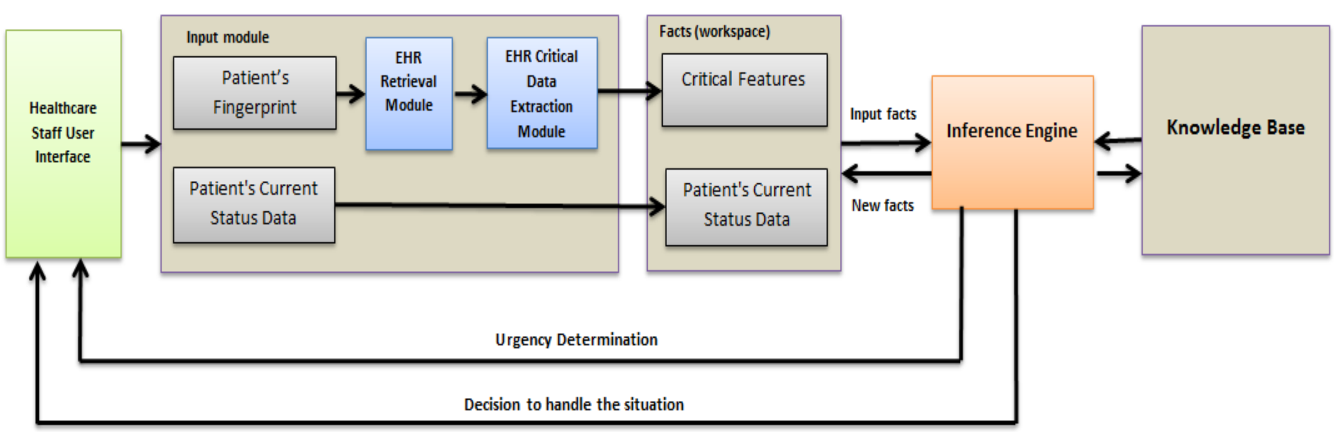

Figure 4. Structure of the proposed CMEDSS

5.1 Healthcare Emergency Staff User Interface

The user interface is the means of communication between a user and the CMEDSS problem-solving processes. The CMEDSS should include enhanced interfaces that enable automated data capture as opposed to manual data entry and that "fit" with the healthcare staff's emergency care processes as opposed to "getting in the way" of their time-critical work.

It has to be able to accept the queries or instructions in a form that the user enters and translate them into working instructions for the rest of the system. It also has to be able to translate the answers, produced by the system, into a form that the user can understand.

5.2 Input Module

The input module deals only with the information submitted by the user, it forms a gateway to the facts workspace. It accepts two inputs from the user, the patient's fingerprint and his current status data. Then it uses the patients fingerprint to retrieve his EHR from the EHRs database, through the EHR retrieval module. The EHR is then passed to the EHR critical data extraction module, which extracts critical and important information from the EHR, this module is needed because the EHR is large and the CMEDSS does not need all information in it. The critical information needed by physicians needs to be determined by emergency and critical care experts (e.g. blood type, diabetic, heart disease, etc.), then defined in the EHR critical data extraction module. The input module then passes the extracted critical features regarding the patient and his current status data to the facts workspace.

5.3 Facts Workspace

The facts workspace is an area in the computer storage where CMEDSS stores the facts it has been given about situation and any additional information it has derived so far. It is also called blackboard, scratchpad or working storage. It includes the facts inserted by the input module and the facts derived by the inference engine during the reasoning process.

5.4 Inference Engine

The heart of the CMEDSS is the inference engine. It accepts the input facts and chooses rules from the knowledge base to fire. Its implementation involves issues such as data structures, searching, sorting, pattern matching (recognition), and probability calculation. Many ready-made inference engines are available in the market and can be used for any intelligent DSS. Examples include OPS5, VP-Expert, EXSYS, KES, M.1, and Personal Consultant [33].

The inference engine produces two types of decisions, one regarding the urgency level of the patient status and one regarding a decision to handle the situation. The urgency level determination is important as proposed in [15, 16, 17, 18, 19, and 20] in order to ensure that the patient will receive medical intervention in an appropriate time frame when he reaches the hospital, it is critical for the health outcomes of the patient and also it reduces costs occurring from misappropriation of emergency resources. The decision to handle the situation, implements emergency medication standards to deal with the patient's situation including life support protocols, recommendations for data acquisition, diagnosis, proposing possible courses of action and therapy.

5.5 Knowledge Base

The expertise of the CMEDSS is represented in the knowledge base and the strength of the CMEDSS is reflected by the strength of the knowledge it possesses in its knowledge base. This includes best emergency care practices about emergency triage, diagnosis in the emergency, critical care medicine, and pre-hospital treatment of each specific health condition. All this knowledge must be taken from an expert and encoded into the knowledge base either by manual methods using a knowledge engineer as in [13] or using automatic knowledge acquisition methods like inductive learning, naïve Bayesian learning, generic algorithms learning, or artificial neural network learning.

6 Conclusions and Future Work

The use of decision support systems for enhancing quality and efficiency of medical decision-making has been flagged by many researchers. However, the greatest part of researches conducted around medical decision support systems were aimed to be used in clinics. Few researches proposed the use of decision support systems in emergency departments due to the greater challenges in emergency settings. And this paper is the first paper to introduce the use of an emergency decision support system in emergency ambulances as well as in emergency departments.

This paper presents a high level design of a comprehensive medical emergency decision support system based on artificial intelligence and the patient's EHR. We proposed the use of the patient's EHR in the decision making process which is the major contribution of this paper (in addition to introducing the use of DSS in emergency ambulances). This system is expected to improve not only the quality of treatment provided to patients in pre-hospital emergency settings, but also the quality and timeliness of the emergency response when the patient reaches the emergency departments.

Future work includes the implementation, testing validation and refinement of the system.

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