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A New Architecture for Intelligent Clinical Decision Support for Intensive Medicine

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Abstract

Real-time and intelligent decision support systems are of most importance to supply intensive care professionals with important information in useful time. The work presented hereby shows an architectural overview of the communication system with bedside devices such as vital sign monitors. Intelligent Decision Support System for Intensive Medicine (ICDS4IM) goal is to ensure information quality and availability to Intensive Medicine professionals to take supported decisions in a mutable environment where complex and unpredictable events are a common state. Therefore, this work focus on Health Information Systems, Interoperability and Information Diffusion and Archive. Moreover, communication standards and the usage of a new technology such as containerization are discussed.

Keywords: Health Information Systems; Intensive Medicine; Decision Support Systems; Containerization; Interoperability

1. Introduction

"Information is power" [1]. Nowadays, we live in a world where everything we own and use generates data, ranging from mobile phones to wearables, such as smart watch's or bands, from refrigerators to medical devices. Hence, the ability do transform raw data into valuable information is one of the main subjects studied by the scientific community. In addition, data and information are the main keys to the success of Decision Support Systems [2]. ICDS4IM - Intelligent Clinical Decision Support System for Intensive Medicine is a global multidisciplinary project which aims to extend the actual state of the art in order to support clinical decision-making. Indeed, it is intended to use intelligent agents to perform several tasks automatically and add the usage of Data Mining techniques in order to make predictions and assist health care providers in the process of decision-making. One of the most remarked advantages of Decision Support Systems, undeniably, is turning the decision-making process faster and more accurate, leading to less mistakes and better decisions [2]. In Intensive Medicine unities, professional tasks may vary from routine tasks

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to highly unique and complex problems, requiring conscious decisions based in deep assessment and analysis [3]. ICDS4IM, more specifically in the Intensive Medicine Department, where decisions are crucial and most of the times must be taken in fractions of a second [3]. This work presents an architectural outline, based on AIDA - Agency for Interoperation, Diffusion and Archive, Nextgen Connector, communication standards and containerization. More specifically, integration of data from bedside monitors, which are a rich source of information, will serve as foundation to future Knowledge Discovery and Decision Support Systems, that could aid Intensive Medicine professionals take decisions, based on more reliable information. This manuscript is divided into five sections, beginning with this introduction, followed by background where foundations for implementing ICDS4IM are shown. Section three describes some of the main tools used and their part in the overall process. Afterwards, section four, entitled ICDS4IM, presents the technical description of the project, its main architecture and a SWOT analysis. The manuscript ends with conclusions and future work.

2. Background

2.1. Health Information Systems

Health Information Systems can be described as Systems that are able to store, process and exchange data, but more than that are able to ensure the spread of information and knowledge in healthcare environment [4]. Hence, such systems are required manly for clinical activity support but also for planning, organizing, executing and evaluating the healthcare services. Therefore, the main goal of Health Information Systems is to improve the efficiency and quality of healthcare services maintained in healthcare facilities, leading to several advantages such as resources optimization and reduction of the number and incidence of medical errors [5, 6].

Healthcare has long ago become a science based on information [7]. Even so, Healthcare Information Systems have gained great importance and have grown not only in quantity but but more importantly in quality. Currently, there is an information overload, making of vital importance to infer which information is relevant and which information should be feed into Decision Support Systems [8]. The scope of information inside the healthcare sector vary from clinically valuable patient-specific to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting. During the past years, Healthcare Information Systems have a very attractive topic for Computer Science researchers. Moreover, such systems have great potential for the amount of data available for knowledge discovery, information retrieval, integration, automation and decision support applications. These main topics show where medicine and health information systems technologies and methodologies for problem solving may overlap [8].

2.2. Intensive Medicine

Intensive Medicine, as one of the domains of healthcare, embraces its dynamic nature. It is surrounded by the uncertainty of clinical decisions and treatments, which fuse to make a complex and often difficult context for clinical practice [3]. Intensive Medicine Departments deal with patients in critical conditions leading to an urge to produce quick and effective decisions under great amount of pressure. It is really important to realize the large volumes of data created by, not only all the devices, but also by the physicians registers, being them nurses or doctors [3].

2.3. Interoperability

Health Information Systems can be outlined has a wide variety of distributed, heterogeneous and ubiquitous systems, that most of the time speak different languages, integrating data from medical records, equipment and devices, which are customized by different individuals, which aim at different goals [7]. Likewise, these systems are a set of software applications that most likely will have problems or not interact at all with each other, thereupon creating silos of information [8]. Currently, despite the new technological advances, there is still a long way to achieve full interoperability in a healthcare unit [8]. The concept of Interoperability goes beyond Information Technology, and crosses paths with organizational aspects of businesses. Stable workflows mean that business processes are smoother and users can access information in a easy and non obscure manner. In the last years many projects have pursued the interoperability of Healthcare Information Systems, and tackling this issue from a technical approach only is one step to fail [9]. Indeed, distinct paths have suggested solutions based on specific standards and technologies, in order to satisfy the needs of a particular scenario. Unfortunately, there is no global interoperability framework, which works seamless for whatever case arises.

2.4. Agency for Integration, Diffusion and Archive of Medical Information

Agency for Integration, Diffusion and Archive of Medical Information (AIDA) has been in the market for several years [10]. This framework provides intelligent electronic workers, commonly called pro-active agents that are responsible for managing and saving the information and answering to requests, with the necessary resources to their correct and on time accomplishment [10]. It proposes an aggregated solution to integrate, diffuse and archive information under a dynamic framework. As a result, knowledge is spread with every system that needs it whenever, wherever needed. Indeed, to build systems for healthcare environments, infrastructure must meet a wide range of basic requirements with respect not only to security, but also reliability and scaling. Granting access to clinical databases, agent technology may provide answers to those who give assistance to patients with a maximum of quality and counting on medical evidence [10]. AIDA also supports web-based services in order to facilitate direct access to information and communication facilities set by third parties. In this project, AIDA is the ground framework, and communication standards and tools will be deployed within its approach. Therefore, integration and interoperability are made easy and simple, not only for existing systems but for new systems to come. Due to its design, new devices should be easily integrated and this new approach intents to enable a better design to overcome this goals.

3. Tech and Tools

In this section, a brief introduction to all the tools and technologies used to outline the main ICDS4IM architecture will be presented, namely the communication standards, integration technologies and data storage management.

3.1. Healthcare communication standards

One of the most challenging tasks within healthcare integration and interoperability is the way that information is spread throughout several vendors, without any losses or errors, hence ensuring its integrity and quality. Health Level 7 version 2.x (HL7v2) provides a standard communication method that enables communication between all the edges of the system which will be integrated. HL7v2 is an international communication standard that enables the sharing of electronic health information [11]. Exchange of data in HL7 format is not limited to Health Information Systems or in a more simple approach software. Medical devices of the new era are becoming more and more connectable, and several communication protocols are available. This is of paramount importance since it implies that on one hand health information systems should be are concerned with communication standards and technologies, and on the other hand, also the medical equipment must deal with such characteristics [11].

3.2. Nextgen Connect

Nextgen Connect, formerly known as Mirth Connect Engine, with its open source, is currently in version 3.x, and it is a cross platform healthcare integration engine [12]. With an intuitive user interface it uses a channel based architecture, which enables connection to several sources and allows different destinations. The main channel inputs and outputs are TCP Send and Receive, file read/write, database read/write, and most important it allows javascript development not only for input and output but also for in between transformations [12]. In this context, ICDS4IM explores the TCP Recieve and send features, where messages can be filtered, routed or transformed based on predefined rules. Used as a specific layer in the new architecture presented within this work, it can produce a better integration experience, with better results and higher performance.

3.3. Containerization

Containerization is a way to provide isolation and resource management in server environment [13]. The term arises from the comparison of the task of shipping containers, which is a standard method to store and ship any kind

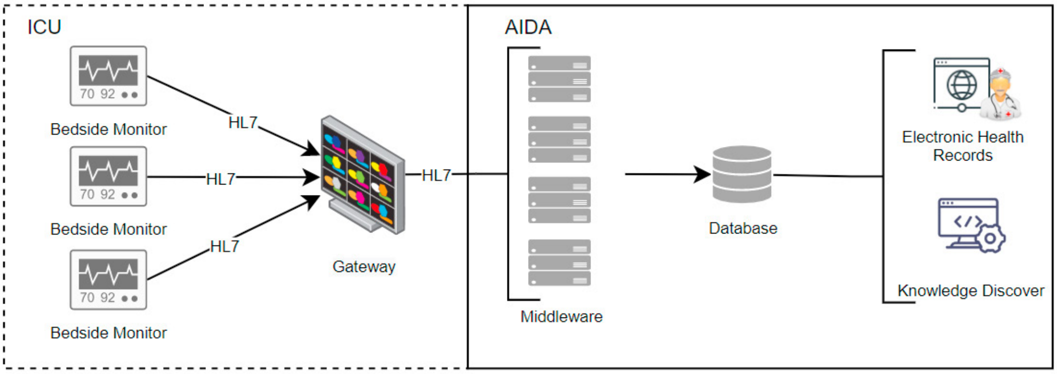

Fig. 1. ICDS4IM Architecture

of cargo. A software running inside a container provides a generic way of isolating the process from the rest of the system using the overall resources of the host machine. Hence, one can boot an entire process just by rebooting the container, and not affecting the other containers in the same system. Furthermore, data migration and restore are made easy on the go, since storage is allocated in the host hard drive. Containerization ensures same level of isolation and security as a virtual machines, being more tightly integrated with the host operating system.

Containerization does not depend on hardware emulation and it provides performance benefits over full virtualization, but restricts the number of supported operating systems which can be spawned as guest operating systems. It is impossible for example to boot Windows in a Linux/Unix Container [13]. Therefore, this technology presents several advantages in its use within the scope of ICDS4IM project.

4. ICDS4IM

4.1. Architecture

ICDS4M will have a modular architecture enhancing scalability for future implementations. Fig 1 presents the main components of the system, making easy to understand the usage of communication standards, containerization and AIDA.

In particular, bedside monitors produce an huge amount of data and a gateway component will act as intermediate in the communication on the containerization/middleware section. This approach will allow for future integration of new and more sophisticated models of bedside monitors. Moreover, bedside monitors and gateway are in a private LAN, making them inaccessible from any other host in the healthcare facility. This makes the system more safe and reliable, creating a barrier to systems trying to access data to which are unauthorized. Gateway will have another physical address which allows to communicate with AIDA and its middleware. Within this middleware section, and using containerization, one is able to balance the traffic and data load within the several containers, making it more scalable and adjustable to future implementations. This section allows data to be collected and processed in real-time. Database section is installed with software load balancing and hardware clustering, which ensures online access 100 percent of the time. Finally, the data collected will be audited, consolidated, and made available not only to Knowledge Discovery Systems but also to the Electronic Health Record.

4.2. SWOT analysis

As previously stated in the above sections, a modular approach is of great interest in the scope of ICDS4IM project, presenting several strengths and advantages, but also some challenges and threats. In this section a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is performed in order to assess the implementation of the proposed architecture and evaluate its suitability for the ICDS4IM ambition.

4.2.1. Strengths

- Scalable: Allows future integration of new devices and components;
- Highly available: Based in network and load balance, at software and hardware level;
- Interoperable: By collecting information from different sources, large amount of data sets will enable advanced analytics;
- Reliable: Data integrity and quality of information is ensured, by collecting and storing the right data;
- Real-time: The tools and technologies used allow for real-time data collection, enabling users to access critical information to support decision-making process;
- Secure: LAN usage and communication standards usage ensures security to the system.

4.2.2. Weaknesses

- Usage of open-source software, which can make the system progress rely on community sharing and knowledge;
- Low redundancy at gateway block.

4.2.3. Opportunities

- Increased importance of predictive and decision support systems within the scope of intensive medicine;
- Usage of open-source software, which might rapidly accommodate new features and facilitate its migration to other hardware platforms.

4.2.4. Threats

- Lack of investment in healthcare unities due to restrictive governmental policies;
- Low adoption by healthcare professionals, who may be reluctant to adopt decision support systems based on Intelligent Systems into their daily routines.

5. Conclusion and Future Work

The new architecture proposed hereby represents the technical foundation for ICDS4IM implementation. Making use of several important technologies and paradigms, such as Interoperability and Communication Standards, it will possible to build a modular system capable of holding future developments for intelligent decision support systems. The main features of the proposed architecture rely on scalable, reliable and secure technologies, with fast developing curves, thus allowing the agile implementation of new algorithms to provide relevant information in real-time. Taking this architecture as the basis for the ICDS4IM implementation, the next steps lodge in implementation on test and quality environments, in order to assess growth potential and adoption value.

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