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Step towards Multiplatform Framework for supporting Pediatric and Neonatology Care Unit decision process

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Abstract

Children are an especially vulnerable population, particularly in respect to drug administration. It is estimated that neonatal and pediatric patients are at least three times more vulnerable to damage due to adverse events and medication errors than adults are. With the development of this framework, it is intended the provision of a Clinical Decision Support System based on a prototype already tested in a real environment. The framework will include features such as preparation of Total Parenteral Nutrition prescriptions, table pediatric and neonatal emergency drugs, medical scales of morbidity and mortality, anthropometry percentiles (weight, length/height, head circumference and BMI), utilities for supporting medical decision on the treatment of neonatal jaundice and anemia and support for technical procedures and other calculators and widespread use tools. The solution in development means an extension of INTCare project.

The main goal is to provide an approach to get the functionality at all times of clinical practice and outside the hospital environment for dissemination, education and simulation of hypothetical situations. The aim is also to develop an area for the study and analysis of information and extraction of knowledge from the data collected by the use of the system. This paper presents the architecture, their requirements and functionalities and a SWOT analysis of the solution proposed.

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Keywords: Multiplatform Framework, Pediatric Care, Neonatology; Person-centered, SWOT Analysis, Sabichão, INTCare, Intensive Care.

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1. Introduction

Every healthcare professional wants to provide the best health care possible to its patients. As the literature demonstrates, the medication errors in the pediatric specialty are frequent and adverse drug effects could be avoided[1]. The collected data says that about 8% of all the medication errors correspond to the pediatric specialty. It is also estimated that 3% of all the hospitalized patients develop a severe reaction as a consequence of the medication administration during its treatment [1]. Several studies also point out that pediatricians have difficulties in performing all the mathematical operations needed, which causes errors in medication dosages. In some cases, the prescription or the administration error leaded to a ten times higher or lower dosage than the accurate one. Errors are potentially dangerous for the patient and if the errors are not intercepted in time, they may cause a temporary or permanent injury[2].

In every pediatrics patients, the medication dosages are based on the patient's age, body weight, and sometimes the body surface. One problem that pediatric caregivers face is that a big percentage of some drugs, like the parenteral ones, do not come with a pediatric presentation. Calculations may be needed on several stages of the medication process, such as the prescription and the preparation.

In order to overcome these events and the daily needs of medical specialists, a prototype was developed to support the decisions and clinical procedures, namely "Sabichão". This prototype provides over thirty features and has been tested for about 200 professionals so that the impact of each feature in a real environment can be evaluated. The prototype was tested in the Intensive Care Unit of Pediatrics and the Units of Pediatrics and Neonatology of the *Centro Hospitalar do Porto*, the *Centro Materno-Infantil do Norte* and the *Centro Hospitalar Tâmega e Sousa.*

This work is in ongoing research phase, so, this paper has as main goal to present the motivation, objectives, and the framework and architecture designed to answer the concerns found in the prototype developed. The Intelligent Clinical Decision Support System (ICDSS) (final system) will be divided in several layers designed to support the person / user (patient, physician, nurses …) and services / departments. Scientifically this work can be also used as a good practices guideline to develop an ICDSS able to support Pediatric and Neonatology Care Units decision process where the focus is decreasing the number of adverse events and medication errors as well to obtain conclusions regarding its usage. The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis performed help to have a better understanding of the solution proposed.

This paper is divided in eight sections. The first one introduces the work. The second are presenting the motivation, objectives and expected results of the work. The literature review is addressed in the third section. Then forth and fifth section present the methodologies used in this work and the main results achieved using Design Science Research. The solution proposed to the problem present is explained in the sixth section. Seventh section presents the four areas of SWOT analysis area. Finally in the eight section is presented the conclusion and future work.

2. Background

In the daily tasks of a health professional, especially in neonatal and pediatric medicine, several factors must be watched to ensure the normality of all the biological and physiological parameters. During this process the professionals must check a lot of tables and graphics. For example, the tables including the percentiles of weight, height, body mass index, percentage of fat mass and body surface values; as well as the values of normal blood pressure, hemoglobin and blood biochemistry.

The constant calculations and the numerous times that healthcare professionals have to check tables, may delay the medical consultation and also makes human error more likely to happen in the overly execution of those tasks. The automation of these tasks available will aim to make the professional life easier, saving their time, reducing the human error risks during calculations and improving the quality of healthcare delivery.

This project involves mainly concepts in the field of biomedical informatics, especially in the areas of the neonatal and pediatric medicine; clinical decision support systems (CDSS); calm and ubiquitous computing; ambient intelligence; interoperability and Business Intelligence.

The CDSS have highlighted in healthcare institutions due to their importance in healthcare professionals' daily tasks. These systems can support not only the decision about the diagnosis, but also about the prescription, reducing errors associated with medication. This is a very important contribution because these errors can be fatal, especially in the neonatal and pediatric medicine [1, 3].

The work in the area of the CDSS applied to neonatal and pediatric medicine has already begun. It was identified the necessity of this kind of systems, namely tools to support clinical practice and decision.

One example of projects designed to Intensive Care Units is the INTCare. This project intends to support the decision making process in Intensive Care Units (ICU), and, it is currently on expansion to other ICUs, such as pediatric intensive care. This system is based on intelligent agents interacting between them, where the agents work without any human intervention. It is capable of automating the collection, processing and transformation of data, making it a real-time system, enabling the detection and alert when a patient's vital function is not normal [8 - 10]. The framework developed is intended to work as an extension of INTCare project in order to increase the decision-making support in paediatrics units. The framework will be integrated in INTCare main system ensuring a broader support in these areas.

It is intended to provide a system, based on a tested prototype that has a high availability, reliability and portability that communicate with other systems in the healthcare institutions that is planned to be integrated. It is crucial to find strategies to enable physicians to offer better health care, providing better assistance, high quality information and content, anywhere, at any time, and on any device [11-12]. With this tool, the efficiency of the medical care is highly increased, and the occurrence of clinical and medical errors can be avoided and many lives can be saved[3].

3. Work Motivation, Objectives and Expected Results

3.1. Motivation and related work

Despite the impact and quality of the results, some limitations and further research opportunities have been identified so that errors could be avoided. The system availability and portability and consequently the support for the daily practice of health professionals could be increased. With an evolution of the prototype, it will be possible, not only to optimize the whole process of using it but, at the same time gather conclusions concerning its use and the patients on which it is used. Such situation would result in a decrease in the number of medical errors as well as an increase in the medical specialists' available time for care the patient, reducing costs and above all improving the quality of the care provided.

The first prototype was developed in excel by a physician. It was tested using a network-shared folder between the centers in which it is operating and the pharmacy in which the requests are being worked. After a first analysis a set of problems was identified:

- Competition - Previous forms are stored in a single Excel file. Being this already opened in another device it prevents the execution of requests to the pharmacy;
- Availability - is only functional for a specific version of Excel within Office from Microsoft, not working on other widely used and free alternatives of the program from OpenOffice or LibreOffice;
- Efficiency - It is a very complex application that results in a high size document inducing elevated times for both opening and usage;
- Scalability - The structure limits the performance when a number of records become significant;
- Interoperability - It is not directly integrated with any Electronic Health Records or Health Information System.

3.2. Objectives

Aiming to answer to the motivation and overcome the problems identified, a set of goals was defined:

1. Provide intelligent decision support on therapies and procedures in neonatal and paediatric care;
2. Decrease the occurrence of medical errors;
3. Ensure the high availability, scalability and portability of the system;
4. Provide a teaching and simulation version available outside of the hospital;
5. Assure the integration and interoperability of the system.

3.3. Expected Results

With the development of the Intelligent Decision support system it is expected to:

- Increased the accuracy on the prescription of therapies and procedures – physicians will be supported in their decisions on the most appropriate treatments and procedures and be able to evaluate hypothetical scenarios;

- Medical Error Reduction by uniformity in the provision of health care to patients and calculation of drug dosages;
- Increased efficiency in the process of execution and confirmation of the exams requests between the physician and the pharmacy where the solutions will be carried out;
- Extend the use of the tool to more hospital units national and internationally;
- Providing a mobile version of the system to ensure the availability of this at all times of the neonatal and paediatric care;
- Possibility of diffusion, knowledge extraction and simulation outside the hospital environment through a web interface.

4. Research Methodologies

The work methodology is problem-oriented in order to resolve a problem and contributing to make human decisions easier and more efficient. This project is being developed in accordance with one case study, action research, design-science research and using implementation methodologies. This case study is being developed in the Neonatal and pediatric Units and have in consideration the existing systems and the obtained results with the prototype. The framework will be inserted in a real context and it is strictly necessary a continuous action-research in order to can circumvent the challenges that arise. Using the data provided from the case studies, the solutions designed based on the action research tasks and the results obtained, the final system will be implemented in the Pediatric Intensive Care Unit and in the Neonatal and Pediatric services of *Centro Hospitalar do Porto* [9-10]. In this work an artefact (CDSS) will be produced. Design Science Research is the main methodology and it was chosen to support the artefact development and assessment.

5. Design Science Research Process

All the research work can be framed in a research methodology: design science research (DSR). DSR has as main goal develop an artefact that as the desired proprieties and it is able to solve a problem. DSR is divided in five phases:

1. Awareness of a problem: to pick up a problem by comparing the object under consideration with the requirements and specifications.
2. Suggestion: to suggest key concepts needed to solve the problem.
3. Development: to construct artefact for the problem from the key concepts using various types of design knowledge.
4. Evaluation: to evaluate artefacts in various ways, searching different problems that the solution provided shows.
5. Conclusion: to decide if a certain candidate is viable to adopt, modifying the descriptions of the object [13].

In this project firstly it was analyzed the prototype, understood the problems and complaints the prototype shown, and defined the requirements.

Then in the second phase it was suggested a solution. This solution is based in the objectives and expected results presented in section three and in the framework presented in section five.

Currently the project is in third phase: design the architecture and develop the artefact. In the future after the artefact (solution) is developed it will be evaluated in order to assess if the problems found can be solved. If a problem is found, it becomes a new problem to be solved in another design cycle [13].

6. System Architecture

This section provides a detailed description of the components and their interoperability. As mentioned before, the solution provided is based in the objectives and expected results already presented. The architecture developed has as main requirements:

- Scalability – This platform is scalable within the medical facilities and in the number of medical facilities that can connect to the main webserver;
- Availability – Providing permanent availability solutions like offline login and late dispatching of the anonymous information;

- Adaptability – Through the use of web services, the application can be adapted to any HIS;
- Ubiquity and pervasive – The system is always available anywhere and in any device;

This architecture is composed by three major components (Fig 1):

- Webserver – Hosting the website and a database that stores user logins and usage data from all the applications in all the medical facilities it is integrated;
- Database – Each new medical facility must host a SQL database. This database provides persistence for the entire system. It keeps an history, logs, and links the user and the pharmacy applications.
- Interfaces - User and pharmacy applications (e.g. web, mobile or standalone);

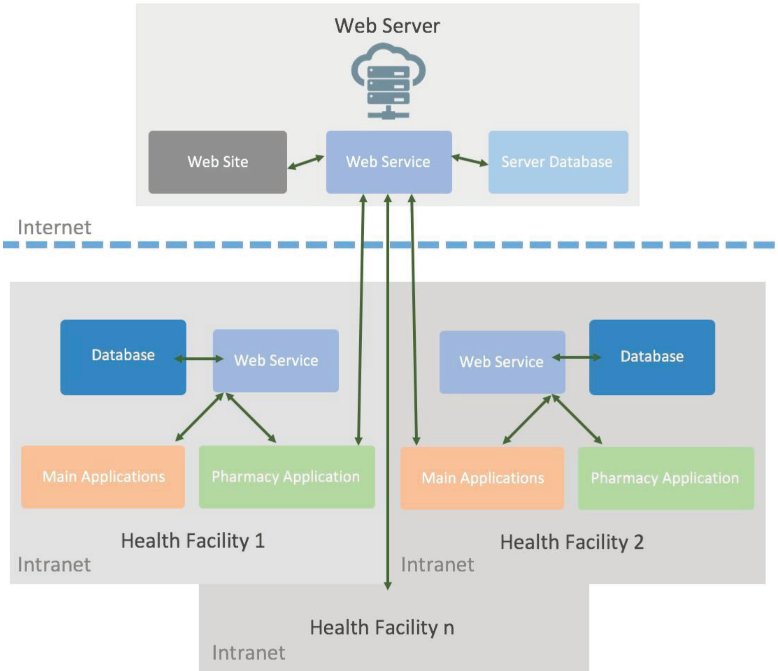

Fig. 1: Framework architecture.

From the interface, users may register to perform online simulations of the offered tools. The registration is validated by the admin. If those users are physicians from the medical centers in which the system is already integrated, they can download the health applications that interoperate with that medical center HIS/EHR, either e-health or m-health. If they are not from the medical center, a simulation tool with no connection to any medical center or pharmacy is provided.

In the same interface, the system's administrator, has access to a management area, in which it can be managed the registered users and registration requests. In the same area, the anonymous information regarding the usage of the platform in all the medical centers is included. The gathering of this information is important so that a real-time overview of the platform can be obtained. Obsolete functionalities can be removed and more ones that are important can be improved and adjusted to the needs of its users.

In the *Centro Hospitalar do Porto, Centro Materno-Infantil do Norte* and *Centro Hospitalar Tâmega e Sousa*, the AIDA platform is used to assure the interoperability among the systems.

The system will require this integration in order to retrieve information about the patients admitted in the neonatal and pediatric services and the Pediatric Intensive Care Unit, as about the physician[8]. The system will register in the medical center HIS any requests made to the pharmacy so they become reachable when accessing the patients EHR.

As can be observed the novelty of this solution is in the fact of all the hospitals are connected to the same webserver. This represents a well-done interoperability between the several systems used in the different services / units / departments. This interoperability only was possible due the development of Agency for Integration, Diffusion and Archive of Medical Information (AIDA), already deployed in all the hospitals [7-10]. One of the benefits of using this system is the integration and interoperability with INTCare system taking advantages of INTCare infrastructure. At same time INTCare will have a framework specialized in neonatal and pediatrics services.

7. SWOT Analysis

In order to analyze the pros and cons of the implementation, it was developed a SWOT analysis, which provides the knowledge of strengths and weaknesses, as an internal perspective of the organization, and the opportunities and threats, as an external perspective of the organization. The SWOT acronym stands for: Strengths, Weaknesses, Opportunities and Threats and, following this section, the various points detected for each of these factors will be properly exemplified.

7.1. Strengths of the application

- Ubiquitous access to a wide range of tools in the pediatric and neonatal areas;
- Immediate access to clinical information of patients;
- Scalability;
- Ease of use;
- Quick access to information;
- User-friendly and Intuitive interface;

7.2. Weaknesses of the application

- Requires connection to the hospital intranet (to access history and to send requests to the pharmacy);
- Requires internet connection (perform login in the application and the dispatch of the usage data to the webserver);
- The addition of a new medical center is not automatic (a database is required, and the interoperation with the new medical center must be configured – web service).

7.3. Opportunities of the application

- Provide the tools to the physicians' daily needs across platform;
- Modernization and organizational development;
- Increased accuracy on the prescription of therapies and procedures;
- Medical Error Reduction;
- Increasing expectation of citizens to obtain faster and reliable responses of clinical services;
- Prototype has already been tested;
- Will be provided for free.

7.4. Threats of the application

- Competition/market pressure;
- Lack of acceptance to resort to new technologies by healthcare professionals

It can be concluded that the proposed application has many positive features for the physicians, the patients and therefore, the hospitals in which it is deployed, endowed with many points such as its availability across platform. It is scalable allowing an immediate access to clinical information of patients and ease of use.

On the other hand, the application has some weaknesses, such as the requirement to be connected to the hospital intranet, and to the internet, even though the last one not required at all times. In the event of a momentary failure in the connection to the internet, it performs the login and stores the information locally. As soon as the connection establishes, the information is dispatched to the webserver. This feature assures the permanent availability of the tool. The slowness is only noticeable sometimes as the network traffic load to the database and Web Service and Database is variable during the day. Some tests are being conducted to evaluate when and why the overload slows down the service. The other weakness resides in the fact that all the medical centers' are not using the same databases. So that the application is able to interoperate with the HIS, some adjustments must be made. This interoperation can be made through a web service in each medical center. It is not possible to access the clinical information outside the hospital intranet for legal reasons.

The SWOT analysis shows a big threat that must be considered, which is the competition from other applications. Until now, it is only a concern because there are not a similar solution.

8. Conclusion

One of the main objectives of this project is to provide these tools to everyone who wants or needs them, either being associated with the hospitals in which it is integrated or not. The aim is to simplify and help not only in the practice of medicine but also its tutoring.

The possibility of all the hospitals and units to be integrated, making the sharing of information easier is one of the higher gains of the solution. The data is shared keeping the patients' security and anonymity in a very high consideration.

In this phase of the work, the main goals were achieved. The prototype was assessed and the main concerns were defined. Then it was assembled a list of possible solution requirements and the delineation of a multi-platform solution.

In this study also it was possible to prove the viability and to understand the receptivity of having in the units an ICDSS centered in the patient and in the service. At same time it was also demonstrated the feasibility of extending INTCare to other Intensive Care Units as is Pediatric.

In a research level, this paper can be used as a guideline to who wants to implement a new and useful solution to neonatal and pediatrics ICU in order to improve the decision making process. With this work were defined the requirements and features that the system should have. The SWOT analysis helped to better understand what are the strengths, such as its ubiquity and scalability and the weaknesses, such as its dependence to the intranet and internet, and the non-automatic process of making it interoperable in a new medical center. Opportunities and threats have been identified. The application is able to improve quality of service in medical practices.

In the future the artefact will be developed according to the requirements defined and clinical staff opinions. This platform will have two versions: standalone and mobile.

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