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Step Towards a Patient Timeline in Intensive Care Units

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Abstract

In Intensive Medicine, the presentation of medical information is done in many ways, depending on the type of data collected and stored. The way in which the information is presented can make it difficult for intensivists to quickly understand the patient's condition. When there is the need to cross between several types of clinical data sources the situation is even worse. This research seeks to explore a new way of presenting information about patients, based on the timeframe in which events occur. By developing an interactive Patient Timeline, intensivists will have access to a new environment in real-time where they can consult the patient clinical history and the data collected until the moment. The medical history will be available from the moment in which patients is admitted in the ICU until discharge, allowing intensivist to examine data regarding vital signs, medication, exams, among others. This timeline also intends to, through the use of information and models produced by the INTCare system, combine several clinical data in order to help diagnose the future patients' conditions. This platform will help intensivists to make more accurate decision. This paper presents the first approach of the solution designed.

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1. Introduction

In recent decades, the growth of the application of technologies to the most diverse areas, as a way to bring more and better knowledge about the area under study was verified. Medicine is one of such areas that has undergone immense changes with the introduction of technologies [1]. More specifically, information systems in medicine seek to ensure greater quality and efficiency, not only in the management of health institutions, but also in the patients treatment [2].

In Intensive Medicine (IM), the computerization of Intensive Care Units (ICU) through advances in technology provided a wide variety of equipment able to constantly monitor various patients' vital signs and their organic systems. This situation results in an increasing amount of data available to better diagnose and treat patients [3]. Initially, these devices were developed to analyze vital signs such as heart rate, blood pressure, among others [4].

The increasing amount of data available in ICU means that there is a greater number of variables that intensivists have to deal with to know which the best decision to make is. Sometimes they have to deal with more than two hundred variables [5] (e.g. vital signs, ventilation, therapeutics, laboratory results, fluid balance, clinical proceedings, others), which hinders the ability to combine and analyze such information in order to decide on the best course of the action.

On top of this, the presentation of medical information is also done in many ways, since it comes from various sources, such as vital signs monitors, ventilators, pharmacy system, laboratories, electronic nursing sheet, among others. The information from these sources can come represented in various ways, some of which are graphs, tables and text. This is because the presentation of information depends on how each of these systems will expose the results of its processes. Medical exams coming from the laboratory will have a standard presentation different from a vital sign monitor, therefore the same reasoning applies to any other location where information may come from. A major concern is the significant number of null and noise values collected that need to be treated before presenting the information to the ICU professional. In this case is necessary to develop an effective process able to make all the Extract, Transformation and Loading (ETL) phase autonomously.

Thus, it is through the awareness of these needs that this research project arises. It is looking to create a platform capable of interoperate with the many hospital systems and provide all the information necessary to the decision making process, regardless of the data source. Gathered and treated information will then be presented in the timeline interface, since the moment the patient's admission until the discharge.

Scientifically, this type of approach is breaking the way of how the information is presented by focusing it in the patient. The studies performed and the test phase made to this prototype using the real data collected in the ICU of Centro Hospitalar do Porto (CHP) proved the solution viability. Clinically, Patient Timeline offers to the intensivists the possibility to view all the information in real-time and in one place, allowing them to make faster, effective and efficient decisions concerning a patient's treatment. This approach also can be followed by other medicine areas.

Besides the introduction, this article is composed by other five sections. Background follows in second and provides background knowledge about the subjects related with the Patient Timeline, such as Intensive Medicine and Intensive Care Units, the Decision Support Systems, the INTCare system and the Timeline. Afterwards, comes section three which identifies the research methodology being used and how it apply to this research. The fourth section describes the Patient Timeline and the features that identify it. Later on, comes the fifth section which is intended for discussion. The last section is where are drawn the conclusions as well as what will be the focus of future work.

2. Background

2.1. Intensive Medicine and Intensive Care Units

Intensive Medicine (IM) is a special area of Medicine that focuses on diagnosing and treating patients with dangerous illnesses considered a threat to the patients' life, and restoring them to their previous state of health and quality of life [6]. These patients are then admitted into Intensive Care Units (ICU), which are special units prepared to continuously monitor the patients' vital functions and organic systems [3]. The monitoring is ensured by various life-support devices, which combined with drugs will make sure the patients recover [7].

2.2. Clinical Decision Support Systems

Clinical Decision Support Systems (CDSS) are a variation of the commonly known Decision Support System (DSS). What differentiates CDSS from DSS is that CDSS are used in the practice of medicine. In this context, CDSS are considered to be computer systems designed to have impact upon medical decisions concerning patients, in the moment that the decisions need to be made [8].

DSS have been a part of healthcare's information systems, however usually played mainly analysis functions for financial and administrative data [9]. But since the publication of the Institute of Medicine, To Err is Human [8], they have been identified as key to increase patient safety by minimizing medical errors.

2.3. INTCare

Having started in 2008, a major concern of the INTCare project was to transform and improve the Intensive Care Unit of CHP information system in order to create new knowledge to the decision process. Until then, records were made on paper and manually. Now with INTCare processes are evolved into an automatic and electronic collection [10]. Implemented in the ICU, the system suffered many changes, as result of an iterative process, and has now become a Pervasive Decision Support System (PDSS) which makes use of intelligent agents to perform its tasks [11]. It is composed of four subsystems (data acquisition, knowledge management, inference and interface), that interact between themselves through the intelligent agents [12].

Acting automatically and in real-time, it aims to help intensivists to understand and predict patient condition and to decide which better treatment should be given to patients. With this in mind, the system can monitoring the patient condition and predict clinical events, such as organ failure, barotrauma, length of stay, readmission, among others. Making use of the ability of ICU to monitor a patient's vital functions, the system is also able to detect and alert intensivists in case these leave their normal range [11].

These features ensure INTCare is capable of giving intensivists new knowledge that helps the decision making process and makes the ICU more effective and efficient environments. This work / study is focused in improving the way of the information is presented to the intensivist.

2.4. The Timeline

A timeline is one of several ways of imaging information. What distinguishes it from others is that it delivers the information, usually events, sorted chronologically. By representing information in a timeline it is possible to realize when each of the listed events did happen, the duration of / between events and possible overlaps [13]. The granularity associated with the timeline always depends on the level of detail that it is intended. Ranging from seconds to days or years, depending on the subject being represented. This information is useful because it allows us to see patterns in certain periods of time and check the progress occurred during the timeframe.

It is more common to see the use of timelines in a historical context looking for cataloging events, such as social movements, epidemics, wars and life history [13].

In the area of medicine, the timelines are more used as historical records of outbreaks of a disease, studies about diseases, or in the daily practice of medicine they may serve the representation of clinical data. In IM, are generally used for continuous monitoring in electrocardiograms, monitoring of expired CO2, blood pressure, among others [14].

3. Research Methodology

The methodologic approach being used in this research project is Design Science Research (DSR). This methodology is based in a set of analysis techniques and perspectives used to do research in Information Systems (IS). It consists of six activities (fig. 1), which constitutes the iteration process developed by Peffers et al. [15]. The first activity Identify Problem & Motivate seeks to define the problem being researched and clarify why there is value in developing a solution for the problem. Following in second, the activity Define Objectives of a Solution looks into the defined problem and knowledge of what can be done, and infers the objectives of a solution. The third activity Design & Development is focused in creating the artifact. In the fourth activity, Demonstration, is demonstrated the use of the artifact in solving the problem. Evaluation is the fifth activity and it focuses on observing and measuring how well does the artifact when applied to the problem. Lastly, comes the six activity, Communication, which ensures the communication of the problem and its importance, the artefact and its usefulness to other researchers and relevant audiences.

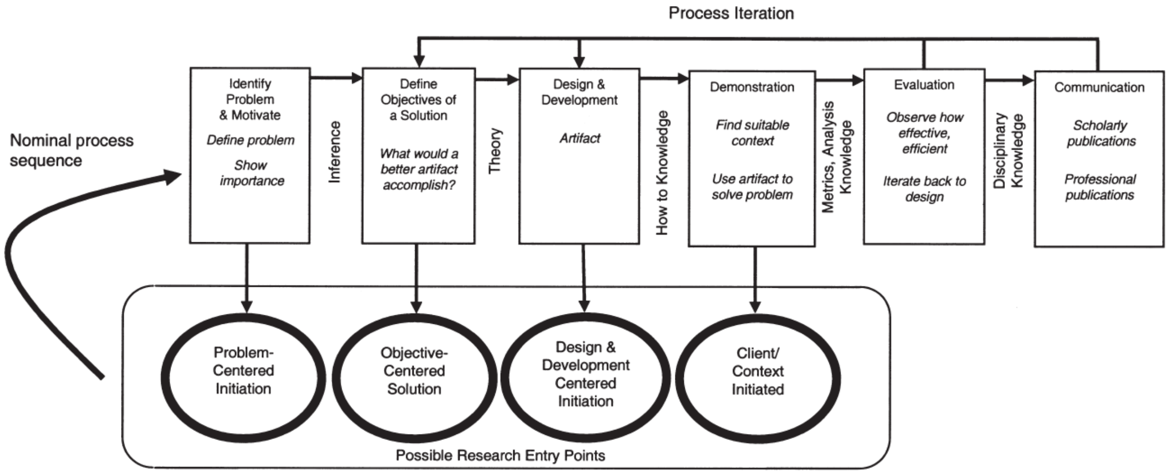

Fig. 1. Design Science Research Methodology Process Model [15].

Under this research project, the iteration process will have an initiation centered on the problem, beginning the moment the problem and its importance are identified. In this sense, it was defined how each one of these six activities relate to this specific research.

The problem here is the way of how the medical information is presented, such as text, tables, and comes from various sources and different platforms. As a result, intensivists have higher difficulty in crossing information in order to read the clinical condition of the patient and decide which treatment should be pursued.

The defined objective for this research seeks to find a solution and develop an artefact able to present the patient information in a better and intuitive way. The solution found was to develop a timeline model to support the decision in Intensive Care Units (ICU). The artefact in production is the patient timeline, which will be subsequently implemented for demonstration in the ICU of the Centro Hospitalar do Porto (CHP). Once implemented, its performance will be evaluated by intensivists that work there. Finally, the disclosure of this artefact and its importance will be made through a dissertation project under work and articles of scientific character, such as this one.

4. Patient Timeline

The Patient Timeline intends to be a Clinical Decision Support System (CDSS) capable of supporting the decision making process of intensivists, through the centralization of data from different data sources, but also by presenting the data in a more accurate and concise way.

It is being developed under the phase II of the INTCare project, and it makes use of the data generated by the INTCare system, which once undergone an Extract, Transformation and Loading (ETL) phase, to be presented in the timeline's interface. This will allow intensivists to acquire new lines of thought, i.e. new knowledge, like observing cause-effect relations between different types of information presented in the timeline's interface. The displayed information will also have real-time access. At same time it will be also possible to combine patient clinical data and future predictions of clinical conditions / diseases.

4.1. Characteristics

Below are presented some of the characteristics considered relevant for the use of the timeline. The characteristics are divided in three aspects: Granularity, Usability and Event Features.

Granularity:
- Maximum: 15 to 15 min;
- Minimum: Decade to Decade.

Usability:
- Choose from a list of patients the one to be displayed in the timeline;
- Dragging to the left and right to see future or past events;
- Zoom in and out to increase the granularity;
- Filter that restricts the categories that appear in the timeline's interface;
- Event search option for words in the title or description;
- Date displayed changes along with the movement of the timeline;
- Adjust date time according to time zone.

Event Features:
- Event title;
- Event description, that may contain text, images, links;
- May have duration, thus containing start and end date, or just start date that records when the event happened;
- Different categories, represented by icons (circles, triangles, etc.);
- An importance level that defines the granularity at which the events will be visible (important if there are many events cluttering the timeline).

4.2. Data Sources

The data sources that will be providing information for the Patient Timeline to present, are the same ones that are already supplying the INTCare system. Therefore the data provided comes from six different data sources [11]:
- Vital Signs Monitor (VS);
- Electronic Nursing Record (ENR);
- Electronic Health Record (EHR);
- Laboratory (LAB);
- Drugs System (DS);
- Ventilation Monitor (VM).

Some of these data sources provide data to Data Mining (DM) models, which have as purpose the prediction of patient's future health condition as well as the suggestion of treatments based on those predictions. Then it is possible sending alerts warning the intensivists in cases, such as when a patient's vital signs leave their normal range for a prolonged time. The results of these DM models and alert system will also be displayed in the Patient Timeline's interface, to support intensivists' decisions.

As already mentioned some of the data collected are not in acceptable ranges, presenting missing and noise values. To overcome this problem an ETL process was designed recurring to the help of intensivists in order to automatically process the data collected and to present it with quality, i.e., only the data considered valid. ETL process is executed by autonomous agents already designed and presented in INTCare architecture.

4.3. Guidelines

In order to understand how the implementation of the Patient Timeline can be a successful one, some guidelines idealized by Khalifa[16] were followed. These guidelines will shape the system and help understand what needs should be attended:

- Provide valid and relevant information;
- Messages simple and easy to understand, as the system is more efficient when reduces the time and effort exerted by the user to understand the messages;
- Provide logic clarification that supports the displayed information, thus increasing the reliability and credibility of the system;
- Should serve as a way to reduce time and effort;
- Being integrated with the operation of the clinical work, otherwise risks not having the desired effect and perhaps no use;
- Increase the responsiveness and the existing system operating speed;
- Be integrated with the hospital information system, so that there is no need to introduce redundant information;
- There is a continued maintenance effort associated with the operation.

4.4. Timeline Example

Below in Fig. 2 it is possible visualize a simple example containing a few variables about a patient's results concerning vital sings and exams from data collected in the ICU of CHP. In this example it is possible to observe data from a date (February, 20, 2015), a short period of time (15 in 15 minutes) and two types of data sources (LAB (green) and VS (blue)). By clicking on the variable is possible to verify the patient value. In other cases it is also possible to automatically show the variables values, it depends on the way of the intensivist wants the information.

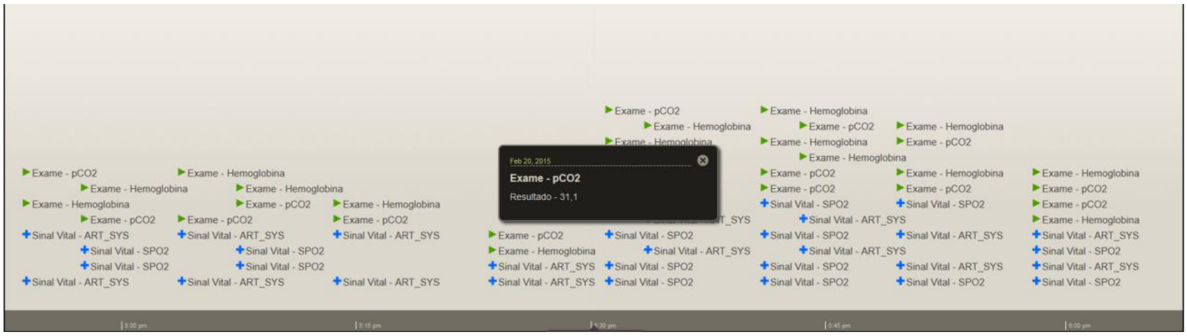

Fig. 2. Patient Timeline.

5. Discussion

The Patient Timeline is looking to create new knowledge by shaping the way of intensivists visualize information. It still is a research project under work, but has already been discussed and validated by professionals working in Intensive Medicine.

Its characteristics provide a wide range of control over different aspects of the timeline, which focus on creating an environment that is easy to understand and use. With this new platform, the intensivists can consult all the patient data that they consider fundamental to take their decisions.

They can consult past data, current data and future predictions. All the platform modules are running in real-time and uses autonomous agents to perform the ETL tasks. At the moment, in this first designed solution it is possible crossing data provided by Vital Signs monitor and laboratory results.

The fact of only being presented valid information helps to improve data quality and its security because the intensivists will make decisions based in real data associated to the patient in analysis. The higher gain of this solution is in the data quality (the way in which data is collected, processed and validated), the number of information available in the moment of decision and the way it is presented.

6. Conclusions and Future Work

This research provided useful information about how a new way of presenting information can, not only, facilitate intensivists' jobs, but also to help reducing medical errors which are an important issue. The necessity to improve the quality of care has been highlighted, but it is an ongoing process. This Patient Timeline is a step in this process of rethinking how quality of care can be improved.

In general the intensivists are very motivated with this new solution and the possibility of, in the same platform, combine several data types and sources, helping them to make their own analysis. By increasing the number of data available and put it in an intuitive and readable way it is possible to contribute to the reduction of the number of medical errors and consequently improve the patient quality and safety.

This new approach opens new doors in the Intensive Medicine where there are several medical devices using data streaming and data collection in real-time, showing the necessity to analyze the clinical information with significance (revealing patients' problems) in few seconds.

As future work, it is being looked upon how the Patient Timeline can be turned into a more pervasive environment, allowing its presence in mobile devices and such. Increasing the number variables and data sources present in the timeline is also part of the work ahead of this research. The timeline's main interface has been developed though it may suffer some changes as result of customization. The data to be presented in the timeline is still under an ETL process, which will ensure the quality of data presented.

The main goals / challenges to the final solution is to increase the number of data available (by including variables provided from all the INTCare data sources and increase the number of information available for each variable), to improve the interface (the way of the data is presented) and to increase the number of functionalities available. In the future, will also be possible to personalize data crosses (selected by the intensivist), presenting only critical data (hiding the normal data or unnecessary information) and alerting the intensivist when it is verified a patient condition change.

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