Pervasive Business Intelligence in Intensive Medicine

An overview of clinical solution

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***Abstract*— In the Intensive Care units, the information and data collected have a high value. It can help the physicians to take the best decision in the patient best interest. In this field, it is imperative to have the information available anywhere and anytime using Business Intelligence Concepts. Pervasive Business Intelligence (PBI) arises as a new technological field. This solution is focused on a person-centered approach, where the patients and the clinicians are the core. In this paper, the Pervasive Computing area is addressed having in consideration the Pervasive Health Care and the Intensive Care units. At first, the Strengths, Weaknesses, Opportunities and Threats analysis are presented, and then an overview of a PBI solution is described.**

Keywords-Pervasive; Business Intelligence; Intensive Care Unit

I. INTRODUCTION

The technological developments related to the diminishing of electronic components have been enormous. At the same time, the creation and spread of the Internet, connecting all machines and providing the worldwide sharing of information capacity reinforce the value of computing. Also the developing new techniques and new technologies, on par with an ever-growing capacity of miniaturisation of the devices and their cost reduction, developed the research capacity in this area.

Huge advances were achieved regarding the portability and storage capability, as well as new arrangements of human-computer interaction and wireless communication technologies, allowing to find computing and communication technologies anywhere and anytime. This situation has allowed and potentiated new interactions between people and their physical environment.

Especially in the field of healthcare, the Business Intelligence (BI) systems advancements have been enormous and especially in the latest years, many solutions have been implemented, given the vast quantity of data to gather and process. In the intensive health care units, the amount of data to pick increases exponentially, many times collected in real time. The need to make available the gathered data is of vital importance for the health professionals in these units. To access the patient's history, at any time and from any place starts to be a need for these intensivists.

In this article, we aim to understand the concept Pervasive, its appearance and joining of the Pervasive Healthcare with the BI systems in this field. This work may, therefore, serve as a guide to those who, in the future, aim to insert Pervasive in the BI systems.

This paper is divided into four sections. After a briefly Introduction, the related concepts are presented in Background Section. Then, in Section 3, the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is presented, and a brief solution analysis is done. Finally, some conclusions are written, and the future work is mentioned.

II. BACKGROUND

This section presents the related concepts of the work.

A. Pervasive HealthCare

The definition of the term Pervasive is, according to the free dictionary, *"to spread something widely and deeply; affecting all aspects of something."* As in the Merriam-Webster dictionary, Pervasive means *"to exist in each part of something; spreading to all parts of something."*

Applying the concept Pervasive to the health field arises the Pervasive Healthcare (PHC) concept. PHC is considered an important area of research [1]. These systems have a dynamic structure and configuration, and an adequate understanding of these structures and the communication between its components, as well as the warranty of a proper and timely execution, is crucial. Pervasive Healthcare is one of the developing technologies using the Pervasive computing paradigm [2]. Pervasive computing presence provides an innovative way for the data transmission from medical applications. Currently, it is used wireless technology in various health domains [2].

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For Rafe and Hajvali [1], Pervasive Healthcare is characterised by complex information, a dynamic number of interesting parts (stakeholders), and by ubiquitous computing, which connects perfectly the digital infrastructures in our daily lives. It gathers, processes and distributes "any kind" of personal information and contextual data at any time [1]. Pervasive Healthcare demands knowledge of the standard individual functions so that it provides the advanced detection of diseases, changes in functionality. It also provides pro-active prevention, as well as health services to predict individual well-being. This means that Pervasive Healthcare requires information that covers a person's entire life, including data on the personal behaviour, lifestyle, emotions, genealogical data, social data, psychological functionality and environmental sensors data [1].

Pervasive Healthcare is considered a key factor in the reduction of expenses and it is known for allowing improvements in disease management. The advances in communications technologies and wireless networks provided the acquisition, transmission, and treatment of critical medical information in real time [8].

B. Understanding Ubiquitous Computing

For M. Weiser [3], Pervasive computing is the most recent paradigm in computing, known as Ubiquitous Computing (Ubicom). Saha [4] foreseen that the Pervasive Computing (PerCom) devices would not just be personal computers. PerCom is also much smaller devices. It can be invisible appliances incorporated into almost any type of object that you can imagine, including cars, tools, household appliances, clothing and various consumer goods, all communicating through continuously more interconnected networks.

Currently, Ubiquitous computing represents a new direction in researchers about the integration and use of computers in people's lives and aims to reach a new computing paradigm, in which exists an elevated degree of penetration and ample availability of computers and other IT devices, with communication capabilities in our physical environment.

Beyond our personal computers, various computing devices incorporate physical places and interconnected objects fixed or mobile, the latter usually being wireless.

Ubiquitous computing already represents, in fact, a new computing paradigm, including the assumption that computers should "disappear" in the physical environment, becoming an integral part of such.

The Pervasive systems and ubiquitous technologies are ever more present in the domains of almost all businesses, improving the method of fulfilling them. In more personal or social areas, they are used principally to improve people's quality of life.

As examples of technology innovations, we have iPad Mini and the iPhone 6 (both devices are from Apple) or the Samsung Galaxy Tab. These devices have, for example, A-GPS, camera, microphone, with 7-9 hours of battery, 4G Internet and Wi-Fi connection, digital compass, accelerometer, environment light sensor, etc.

C. Understanding Pervasive Computing

For D. Saha [4], Pervasive computing (PerCom) would be, in the future, "omnipresent" combining ubiquitous open-source applications with the quotidian activities of the human being.

From PerCom's point of view, the environment would be saturated with a series of computing and communication resources very well blended with daily life. It allows the user to interact with a smart environment from everyplace, using an apparently invisible infrastructure from various devices/communication/computing, fixed and wireless networks. PerCom would create a digital omnipresent, sensible and adaptable environment for the human needs, characterised by the following essential elements: Pervasiveness (omnipresence), transparency (invisibility) and intelligence [4].

Pervasive computing would provide surprising enhancements in our capacity to connect and communicate [9]. It would gradually become integrated into our lives and daily activities, through natural ways of human-computer interaction, such as it has been verified. Even currently, the benefits and applications of Pervasive computing are far from being finished.

Various business fields, such as insurance companies, government agencies, health organisations, etc., can still get multiple benefits from Pervasive computing.

What was initially limited to the development of technology to make Pervasive computing more than a vision, as clearly gone beyond the first frontiers reaching the development of applications for various organisational domains [5]?

D. Pervasive Mobile Architecture

PerCom, as mentioned in [4], was pointing to the world where every object, every building, and even everybody would become part of a network service, where there is an expectation that the number of Pervasive devices would multiply rapidly.

Ideally, PerCom should approach all and every device on the globe with embedded active/ passive intelligence. These new smart gadgets or smart devices would be fit into microcomputers that would allow the users their connection to intelligent networks, and therefore, gain direct access, straightforward and secure, to information

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and services. These devices would then be mainly known as Pervasive devices [6].

One of the most common, current examples are the GPS based sensors, which provide location data that is translated into an internal representation of latitude, longitude, and altitude. Then advancing in time, we can verify that for Prabhakar et. al [6], there is more and more advances in mobile technology devices, such as, for example, smartphones, these technologies will become more Pervasive and omnipresent. Therefore, this verified reality in 2015, was in 2005 just a forecast/vision almost impossible to believe.

E. INTCare

The INTCare system was elaborated by Portela et al. [7] and implemented in the Intensive Cares Unit (ICU) of the Santo Antonio's Hospital, Porto's Hospital Center (CHP). It is an intelligent decision making support Pervasive system, composed of a group of integrated modules that execute all chores regarding knowledge discovery in an automated way and in real-time. In accordance to Portela et. al [7] INTCare can present anywhere and at any time information/knowledge, essential for the clinic decisions and whose primary purpose is the blending of a group of data sources to obtain interoperability advantages and the use of Data Mining models.

The INTCare System has improved the way the data is gathered and how it allowed the performance of manual actions made by the ICU professionals. It allows an entirely automatic collecting data process, in real-time, and besides that, it avoids paper registry [7].

In [8], it is referred that the INTCare health system consists of a Smart Decision Making Support System and Pervasive (SDMSSP), focused on the field of intensive medicine, developed in the unit of intensive care at Santo Antonio's Hospital, with the following characteristics: Online training; Real-time; Adaptability; Data Mining models; Decision Models; Smart Agents; Precision; Security; Pervasive/Ubiquity; Privacy; Safe access from the exterior and Use policy.

III. RESULTS

The achieved results are divided into two groups: SWOT and web application.

A. SWOT

Figure 1 presents a SWOT analysis of the Pervasive concept inserted in Business Intelligence Systems, developed while keeping in mind the context of critical healthcare area.

Figure 1. SWOT Analysis

B. Application

In this work, several dashboards were developed (sum, average, mode, max, and min). These panels address Admissions from emergency, urgency, other ICU, other hospitals, other, Admission type (urgent or programmed), disease, vital signs, ventilation, therapeutics (medications, dosages), patient information (sex, age), clinician, date (day, month, year, hour), type and others. In the next images, it is possible to observe some of the contents developed. Figure 2 refers to a dashboard where it is possible to verify the total number of patients admitted to the Intensive Care Unit (ICU). Here, we can know the admissions regarding the origin of the patients by service (SERVICO, DESP) and the number of admissions by sex (SEX), which, in this case, they were mostly male, with 1738 cases of this sex and only 1139 of the women. In Figure 2, it is also possible to see that 102 patients had a cardiac issue (insufcardiac) and 36 used a pacemaker; 40 patients did chemotherapy and 28 a radiotherapy. Finally, 123 patients were taking insulin.

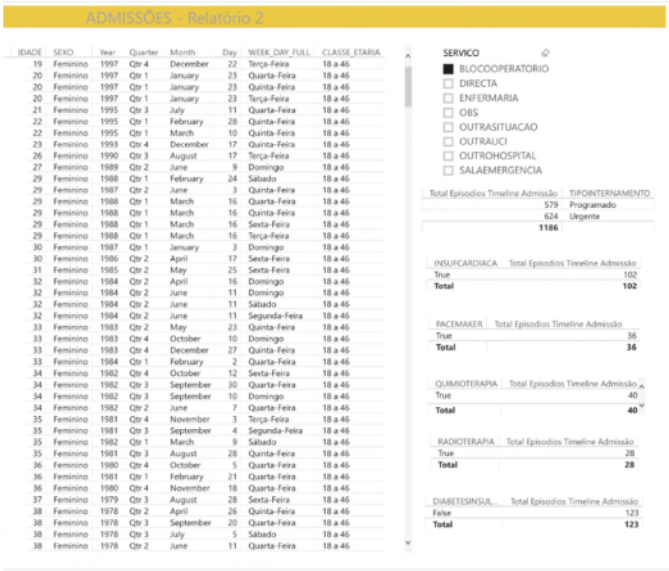

Figure 2. An example of Dashboards developed - total number of patients admitted to the Intensive Care Unit.

In Figure 3, it is possible consulting the data collected from patients admitted to the ICU of CHP and some of their characteristics, such as the episode number of hospitalisation (EPISODIO), process number (PROCESSO), sex (SEX), date Birth (Year, Quarter, Month, Day).

During the period of October 2010 - March 2016, ICU had 2877 patients (1738 Males and 1135 females) admission with an average of 66,91 years old. 50% of the admissions came from either ICU or cardio service (UIHC).

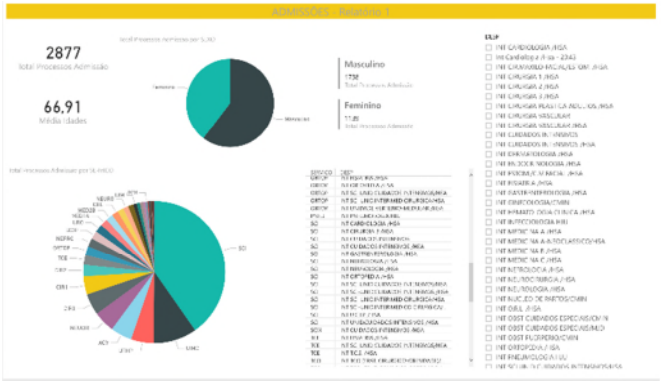

Figure 3. An example of Dashboards developed - data from patients admitted to the ICU of CHP.

IV. CONCLUSION

This paper presents the first overview of a Business Intelligence solution developed in an Intensive Care Unit. In this study, the SWOT analysis shows that the Information Security is the primary concern and the data availability (anywhere and anytime) is the main benefit of PHC. Complementary, this paper also showed the first application images.

After a first analysis, the intensivists consider this application interesting; however, it needs a deeper clinical analysis done by them. A Business Intelligence Application provides only the data in an intuitive way. Then the professionals make the results analysis with the focus on the contribution of it to their decision-making process.

In the future, the intensivists will perform a deep analysis of the dashboards. Other panels are being developed, and then the final solution will be deployed in the real environment.

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