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Pervasive Business Intelligence: A new trend in Critical Healthcare

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Abstract

In the field of intensive medicine, presentation of medical information is identified as a major concern for the health professionals, since it can be a great aid when it is necessary to make decisions, of varying gravity, for the patient's state. The way in which this information is presented, and especially when it is presented, may make it difficult for the intensivists within intense healthcare units to understand a patient's state in a timely fashion. Should there be a need to cross various types of clinical data from various sources, the situation worsens considerably. To support the health professional's decision-making process, the Pervasive Business Intelligence (PBI) Systems are a forthcoming field. Based on this principle, the current study approaches the way to present information about the patients, after they are received in a BI system, making them available at any place and at any time for the intensivists that may need it for the decision-making. The patient's history will, therefore, be available, allowing examination of the vital signs data, what medicine that they might need, health checks performed, among others. Then, it is of vital importance, to make these conclusions available to the health professionals every time they might need, so as to aid them in the decision-making. This study aims to make a stance by approaching the theme of PBI in Critical Healthcare. The main objective is to understand the underlying concepts and the assets of BI solutions with Pervasive characteristics. Perhaps consider it a sort of guide or a path to follow for those who wish to insert Pervasive into Business Intelligence in Healthcare area.

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1. Introduction

The technological developments related to the diminishing of electronic components have been enormous up to the current date. At the same time, the creation and spread of the Internet, and it's capacity to connect all machines and providing the worldwide sharing of information, has come to reinforce the value of computing. Also the growing new techniques and new technologies, on par with an ever-growing capacity of miniaturization of devices and their cost reduction, promoted the divulging of computing. 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 in almost every person, object and places. This has allowed and potentiated new interactions between people and their physical environment. Especially in the field of healthcare, the BI systems advancements have been significant and within the intensive care units the quantity of data to gather increases exponentially, often being gathered in real time. The need to make all of the gathered data available 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 the Pervasive concept its appearance and integration of the BI systems within the Pervasive Healthcare in this field are addressed. This work may, therefore, serve as a guide to those who, in the future, aim to insert Pervasive in the BI systems.

The structure of this work is divided in the following manner: Section 1: Topic introduction and description of the content. Section 2: Theme´s background study. Section 3: Comprises Pervasive Business Intelligence and Critical Healthcare, focusing on Pervasive Mobile Architecture, Pervasive Healthcare, Pervasive Healthcare solutions and Pervasive Business Intelligence. Section 4: Encompasses the discussion of the points presented above and the results obtained. Section 5: Presents the conclusions and suggestions for future work.

2. Background

2.1. Pervasive Healthcare and Pervasive Computing

For Tu et. al [1], the main objective of Pervasive Healthcare is to reach the required quality of the service at any moment and by anyone, regardless of its location and position, along with other restrictions. For Ruotsalainen et. al [2], the reliability is one of the pillars for future personal health systems, ubiquitous healthcare and Pervasive health. Pervasive Information Systems (PIS), allows for a new and meaningful interaction, goes far beyond of the traditional desktop paradigm and introduces new elements in multiple dimensions that approach different domains, such as Human-Computer Interaction and Software Engineering. Because of that, it should be seen as a new class of Information Systems [4]. Essentially, PIS reviews the way we interact with computers through the introduction of new entry arrangements and System capabilities, dealing with non-traditional computing devices that merge perfectly in the physical environment and simulate the way human beings interact in the physical world [4]. For D. Saha [3], Pervasive computing would be characterized by the following basic elements: Pervasiveness (omnipresence), transparency (invisibility) and intelligence. Currently, the benefits and applications of Pervasive computing are far from finished. Various business fields, such as insurance companies, government agencies, health organizations, 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, has clearly gone beyond the initial frontiers, reaching the development of applications for various organizational domains [4].

2.2. Ubiquitous Computing vs Pervasive Computing

For M. Weiser [5], the term "Ubiquitous" refers to the characteristic of existing or being in all places, at the same time. Pervasive computing concerns the computing device's capacity to obtain information about the environment, and reciprocally, the surrounding environment being intelligent enough to detect any computing devices that interact with it. If we take into account the use and meaning of the terms mentioned above, it becomes evident that it is necessary a reflexion and clarification about these meanings, allied to computing. We can therefore conclude that Ubiquitous means to be in various places at the same time, given the idea of omnipresence. Now the concept of Pervasive implies a constant presence, and as in how it is constantly found, fades in the environment, as defined in [6].

Although both concepts are close, *Pervasive* computing seems to have a connotation more related to a physical perspective, localized, in which the computing technology "penetrates" things. The Ubiquitous computing is more generalist, referring to a computing technology, which is found perfectly in everywhere and any place. Lyyten & Yoo, 2002 [6] defined that Pervasive computing has a high level of insertion, but a low level of mobility, where the Ubiquitous computing has both in high levels (insertion and mobility).

3. Pervasive Business Intelligence and Critical Healthcare

3.1. Pervasive Mobile Architecture

Using the wireless sensors network as a means to provide healthcare at a distance, it provides an unique opportunity to reduce the health costs through a more efficient use of clinical resources and the precocious detection of diseases [7]. In the last years, many progresses were made in the development of a number of devices and health services. Strictly speaking, Pervasive Healthcare may be seen as an integration of the unique capabilities of mobile devices, wireless networks, sensors and middleware. A wide array of applications and health services, would very likely improve with the support of these technologies, including the utility, monitoring technologies, mobile and wireless technologies for the storage of health information, file transmission, processing, electronic health registry managed by the patient himself and so forth. A common objective for many organizations is to make Business Intelligence (BI) more Pervasive, making it available to more people and, this way, being able to make BI available for the masses [8]. This BI propagation does not just view the workers, but also the providers and the clients. They constitute challenges for the BI dissemination [8].

3.2. Pervasive Healthcare and INTCare

For Rafe and Hajvali [9], Pervasive Healthcare is characterized by heterogeneous information, a dynamic number of interested parts (stakeholders), and by ubiquitous computing, that connects perfectly the digital infrastructures in our daily lives. She gathers, processes and distributes "any kind" of personal information and contextual data at any place [9]. Pervasive Healthcare is considered a key factor in the reduction of expenses and is known for allowing improvements in disease management and advances in communication technologies and wireless networks providing the acquisition, transmission and treatment of critical medical information in real time [10]. For Larburu et. al [11], the Pervasive Healthcare systems apply information and communication technologies to allow the use of omnipresent clinical data by authorized medical personnel. All over the world, the information and communication technology play an ever more integrated roll in providing and managing health services and medical care, this phenomenon being known as e-Health [12]. The evolution of wireless communication technologies opened the way for the definition of innovative e-Health systems that aim to provide a continuous and remote support to the patients and new instruments to improve the work flow of the medical personnel [13]. Figure 2 shows the process in which the health systems take Pervasive characteristics and where it is perceptible.
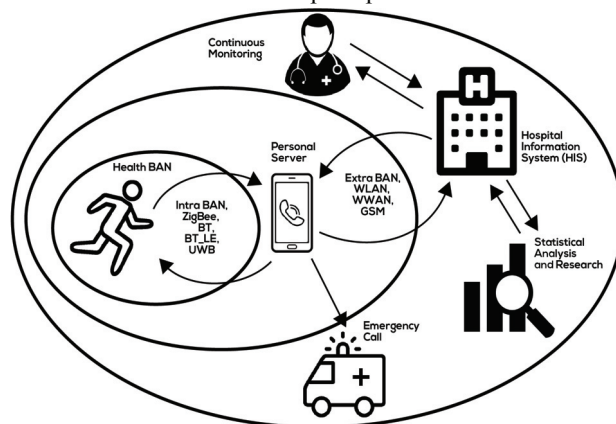

Fig. 1: General Vision of Pervasive Healthcare Systems (adapted from (Rafe & Hajvali, 2014))

For Rafe and Hajvali [13], in these systems, due to communication's security and the real-time execution of each component, the reliability, diagnostic, and immediate and effective control of the disease is very important. It is expected that the messages be transferred in a proper manner through the system and that the data be sent to the patients within an environment in real-time. For Agarwal and Sinha [14], the Intensive Care Unit (ICU) is extremely useful for the rendering of health care to critical patients for their quick recovery. Considering multiple vital factors in a real scenario, an intelligent decision support system could be developed and even work in a more efficient way if associated with techniques of Pervasive de Data Mining. One of the examples is INTCare, an intelligent Pervasive decision support system developed especially for Intensive Medicine. Pervasive computing, when applied to health systems, may potentially revolutionize the medical applications from the next generation and improves significantly the quality of health services. According to Portela et. al [15], decision making may evolve towards a different model, considering Pervasive health, since this constitutes a *"conceptual system for the provision of health care to anyone, at any moment and, in any place through the removal of time and location restraints, simultaneously increasing the coverage and quality of health care"*. Still in accordance to Portela et. al [15], the INTCare system is an Pervasive intelligent decision support system, composed by a group of integrated modules that execute all tasks regarding knowledge discovery in an automatic way and in real-time [16]. INTCare can present anywhere and at any time information/knowledge, essential for the clinic decisions and whose main purpose is the blending of a group of data sources to obtain interoperability advantages and the use of Data Mining models [17]. The INTCare health system has 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 [18]. Summing up, it is general knowledge that the condition of inpatients at ICUs is, by norm, very complex and INTCare is capable of verifying if the previsions made were or not correct, therefore allowing a supervised learning approach [19]. The main objective of the authors by creating the INTCare system, consisted in supporting the decision making process of medical professionals in a Pervasive manner using smart systems [15].

3.3. Pervasive Business Intelligence

Table 1 presents an overview of the concepts that given origin to Pervasive Business Intelligence (Low level = 1| High level = 5). PBI concept is based in the Ubiquity - Existence or apparent existence everywhere at the same time; omnipresence and in the Omnipresence - Present everywhere simultaneously.

Table 1: Pervasive Business Intelligence – Associated concepts.

Area or Theme Concept	Ubiquity	Omni-presence	Embed--dedness level	Mobility level	In Personnel Devices	Network need
Pervasive Healthcare	5	5	1	5	5	5
Pervasive Information Systems	1	5	1	5	1	5
Ubiquitous Computing	5	5	5	5	1	5
Mobile Computing	1	5	1	5	5	5
Pervasive Computing	5	5	5	1	5	5
Pervasive Mobile (devices)	1	5	5	5	5	5
Pervasive Mobile Computing	1	5	5	5	5	5
Business Intelligence	1	1	5	1	5	5
Pervasive Business Intelligence	5	5	5	5	5	5

4. Discussion

Although the Business Intelligence (BI) Systems with Pervasive characteristics will be more a tendency in health care, especially in the field of intensive medicine, there is much to be done for the creation of knowledge in the way intensivists provide the viewing of patient related information to the health professionals. One of the aspects to be considered is the difficulty in understanding the concept Pervasive and its application in BI systems. This work aims

to ease that task, serving as a guide for the intensivist in the drawing and implementation of solutions in the field of Intensive Medicine. Although it has already been discussed and validated by professionals that work in this area, there aren't many solutions either on a national level, or at an international level. It is to be foreseen that technology continues to develop at the incredible rhythm that has been verified so far, especially in the last decade, relatively to the size of devices and the capacity to blend and diffusing into the environment that surrounds us. For that reason, the current emergence of the concept Pervasive BI, will accentuate and even become common rule in the field of Intensive Medicine and in critical health care. Referring the INTCare system that came to ease the decision making by health professionals, other systems will appear, in which, predictably, Pervasive will have a big feature in BI systems. With this work, it is expected to ease the development of solutions with those characteristics, aiding, the work of health professionals and consequently, the conditions of inpatients at intensive care units.

Table 2 presents a SWOT analysis of the Pervasive concept inserted in Business Intelligence Systems, developed while keeping in mind the context of critical healthcare area.

Table 2: SWOT Pervasive analysis for Business Intelligence Systems in critical healthcare area

Strengths	Weaknesses
• Access to information timely and anywhere • Emergency and innovation of Pervasive • Promoted by Doctors with background in intensive care • More motivated team and staff with strong commitment to medical mission • Exclusive access to specific critical healthcare information • Consistent delivery of high quality decision support information • Innovative healthcare services improves and optimizes units capacity • High level of organization / department efficiency through BI systems • Excellent technological infrastructure	• Trust network questions • Confidentiality of information • Shortage of critical healthcare staff • Lack of technological infrastructure in healthcare units • Lack of available / appropriate input information • Possible need for key technical expertise recruitment • Problems on supporting decision-making if information is inappropriate / out-to-date • Ineffective practice information management system • Over dependency of decision support systems in decision-making
Opportunities	**Threats**
• Very large market (hospitals, clinics, etc.) • Decrease in the value of insurance / health equity • Increased emphasis on quality in critical healthcare area • Increased awareness of preventive medicine in intensive care units • Increased managed care business • Arrival / adoption of new technologies • An unfilled critical healthcare need • Information up-to-date • Avoid common pitfalls of clinical decision-making	• Medical staff not available to deal with technology • Privacy and security health hazards • Cost of implementing / extending technology infrastructure • Healthcare regulation laws could impact • Lack of financial resources / budget deficits / decreased health staff / decreased technical staff • Network attack risk making private patient information left unprotected

5. Conclusions

The performed research has provided useful information about the concept Pervasive, the Pervasive Business Intelligence (BI) Systems and their connection to Pervasive Healthcare. The understanding of these concepts may aid the work of intensivists and, eventually, help to reduce medical errors, implementing Pervasive characteristics in

critical health systems. In general, intensivists are already very motivated with this possibility, and conscious that it will help them in the analysis and data access. By enabling the data access from anywhere at any time, it is possible to contribute to the reduction of the number of medical errors and, consequently, improve the quality and safety of patients. The implementation of Pervasive BI opens new doors in Intensive Medicine, where there exist various medical devices that register the flow of data and where its gathering is made in real time, showing the need to analyse the significant clinical data (revealing patient's problems) in little time. Especially in the field of Intensive Medicine, there already exists the technology (software) network (infrastructure), and the habit from users in the use of the applications (health professionals), that eases the implementation of BI systems with Pervasive characteristics. Increasingly, there will be equivalent solutions to INTCare in critical patient's health care units, eventually improved and, in time, dealing with more variables, therefore, the availability of obtained information after the gathering and treatment of data, is of crucial importance for a more assertive, efficient and timed decision. As for future work, the research performed may be deepened, broadening the array of authors studied regarding each concept and the research of BI solutions already implemented that hold Pervasive characteristics, resorting to a wider temporal interval and more human resources. Another suggestion is to use the concepts provided here and the INTCare system structure to improve on it and attempt to apply it in a different setting as to search for more variables that have yet to be discovered in an Intensive Cares Unit that may only be unearthed in a different medical setting.

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