Wireless Networks
https://doi.org/10.1007/s11276-018-01911-6

The development of a pervasive Web application to alert patients based on business intelligence clinical indicators: a case study in a health institution

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Abstract
This paper proposes the development of a pervasive Web application based on business intelligence clinical indicators created with the data stored into the health information systems of a Portuguese health institution in the last 3 years i.e. between the beginning of 2015 and the end of 2017. With this computational tool, it is principally intended to reduce the number of appointments, surgeries, and medical examinations that were not carried out in the hospital most likely due to forgetfulness since most patients who attend this health institution are elderly people and memory loss is very common with increasing age. Therefore, patients and/or their caregivers and family members are alerted via SMS in advance and appropriately by health professionals through the Web application. This alternative is cheaper, faster, and more customizable than sending those SMS using a smartphone. Advantages liked with the use of this solution also include decreasing losses concerning time, human resources, and money.

Keywords Health information and communication technology · Web application · Business intelligence · Data warehousing · Health institution · Elderly people · Caregivers

1 Introduction

The novelty of this project lies in developing a pervasive Web application based on business intelligence (BI) clinical indicators in an attempt to reduce the number of appointments, surgeries, and medical examinations that were not carried out in a Portuguese health institution most likely due to forgetfulness. It is important to note that most patients who attend the hospital are older adults and memory loss is very common with this age group. Therefore, the patients and/or their caregivers and family members are warned of their scheduled appointments, surgeries, and medical examinations via SMS in advance and appropriately by health professionals in order to reduce such numbers.

On the other hand, it is also intended to strengthen the use of health information and communication technology (ICT) in healthcare environments since most current health ICT solutions are still immature according to the scientific community despise their great potential.

Additionally, it is fundamental to refer that this study is part of the research project "Mobile Collaborative Augmented Reality and Business Intelligence: A System to Support Elderly People's Self-care" that involves ensuring the continuity of care of patients (elderly people) and strengthening the communication strategies between health institutions, particularly nursing homes, and patients and their caregivers through technological innovation [1].

Regarding the structure of this document, in Sect. 2, the state of the art related to the research area of this project is described. Thereafter, Sect. 3—"Research Strategies"—presents a brief description of the main research strategies selected to conduct this study. Then, Sect. 4, "Results", presents in detail the results achieved, which include the BI

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Published online: 25 January 2019

clinical indicators created, as well as the architecture of the Web application developed. Thereafter, in Sect. 5, a proof of concept (PoC) is demonstrated, which implies the discussion of the results achieved. In Sect. 6, the conclusion and future work conclude briefly this paper.

2 State of the art

In recent years, the adoption of health information and communication technology (ICT) has been expanding dramatically [2–4]. Even though most current ICT solutions are immature, they are evolving quickly in healthcare, and a brighter future approaches [4].

In short, health ICT consists of the set of all activities and solutions provided by computational resources that allow the production, storage, transmission, access, and use of information in the healthcare industry, and enable people and organizations to interact in the digital world [5–7].

It presents the potential to enhance individuals' health, and increase health knowledge and access to care, as well as to improve the performance of healthcare processes provided, namely in their efficiency and effectiveness, as well as in their significant reduction in time and cost [3, 5, 8].

On the other hand, the concept of business intelligence (BI) refers to the process of collecting, transforming, organizing, analysing, and distributing data from various internal and external sources of information to improve the decision-making process [6, 9]. In this way, based on past experiences, BI transforms a large amount of raw data into useful information for an even more strategic decision-making process [9, 10].

Solutions that resort to BI include the application of several processes including the extract, transform, load (ETL) process that handles the extraction, clean-up, normalization, and loading of data from data sources; the construction of data warehouses (DW) for structuring data in order to facilitate its analysis, i.e. data warehousing; and, finally, the visualization, analysis, and interpretation of the information represented by data [7, 10–12].

In Fig. 1, the general framework of the business intelligence process is demonstrated, which includes the "Data Collection" from internal and external data sources, the "Data Storage" of those data through the construction of a DW via the ETL process and, lastly, the "Data Use" that encompasses potential outcomes such as reporting, OLAP, and data mining [6, 10–12].

However, despite the evolution of BI into a promising field in healthcare, it does not have reached its full potential in health institutions, and several challenges must be overcome regarding essentially availability, continuity, ease of use, and quality assurance [9, 13]. Therefore, the health data that is expected to grow dramatically in the years ahead must be acquired, analysed, visualized, and consumed befittingly.

3 Research strategies

This project was sustained by a set of principal methods and procedures in order to have standards to follow along with an organized path.

First, the main research methodology that was followed is design science research (DSR) since is it suitable for rigorous health information and communication technology (ICT) research projects.

Based on the case study research method, ethnography, and a cross-sectional study, an up-close and detailed examination of the subject of study (the case) was conducted, as well as its related contextual conditions, at specific points in time. It is interesting to note that the Portuguese health institution has established connections with multiple nursing homes located in the north of the country and, therefore, many patients are elderly people.

Data collection predominantly included primary data via participant observation, focus groups, and semi-structured interviews with health professionals of the hospital. Their insights were fundamental to design and develop a Web application according to the needs of the health institution.

As described in Sect. 2, the business intelligence (BI) process can be divided into three different stages, namely "Data Collection", "Data Storage", and "Data Use". The "Data Collection" and "Data Storage" stages were already performed by part of the research team years ago when the health information systems (HIS) were implemented in the hospital. Therefore, this study consisted principally in the "Data Use" stage through the creation of BI clinical indicators and, consequently, the design and development of a pervasive Web application.

Additionally, a proof of concept (PoC)—evaluation method—was performed, through a cross-sectional study, in order to corroborate the feasibility and usefulness of the solution, i.e. to evaluate its impact in the hospital.

Lastly, it is also fundamental to refer that ethical issues are safeguarded through sensitivity, confidentiality, and anonymity guarantees to the organisation and all individual participants involved.

4 Results

The different elements of the target audience of the Web application include patients—predominately older adults, their caregivers and family members (if applicable), and

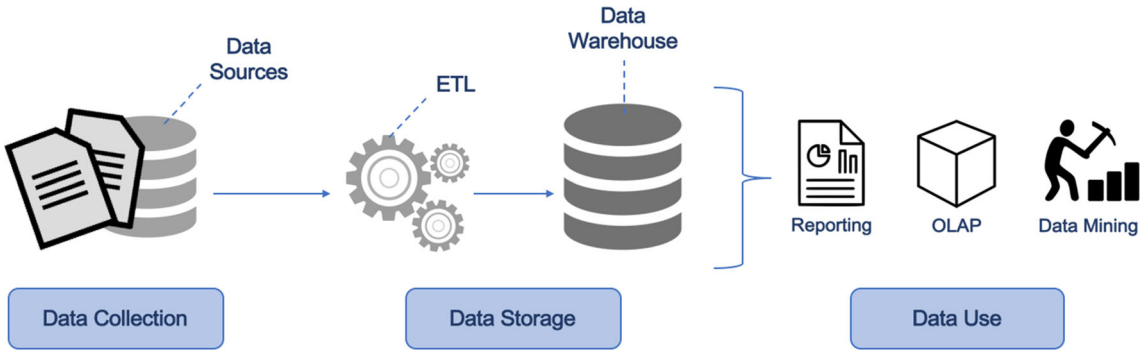

Fig. 1 A general framework of the business intelligence process

health professionals from the Portuguese health institution (case study).

The business intelligence (BI) clinical indicators created are presented in Subsection 4.1. Thereafter, the architecture of the solution is described in Subsection 4.2.

4.1 Business intelligence clinical indicators

As stated previously, this Web application was developed in order to alert predominantly patients and/or their caregivers and family members of their scheduled appointments, surgeries, and medical examinations in the different units of the Portuguese health institution.

As it was expected that many patients did not attend their scheduled appointments, surgeries, and medical examinations, mainly due to forgetfulness, it was decided to create business intelligence (BI) clinical indicators with the data stored into the health information systems (HIS) of the hospital in order to confirm such hypothesis. Most patients who attend the health institution are older adults and memory loss is very common with increasing age.

Therefore, the data warehouse of the case study was studied in order to identify the data that will be used to create the BI clinical indicators. Such study also involved uncovering in which tables the data were stored.

On the other hand, the data stored into the HIS that were used to create the indicators are approximately from the last 3 years i.e. between the beginning of 2015 and the end of 2017. The Web application was developed at the end of 2017 and it is being used by health professionals of the hospital since the beginning of 2018.

Additionally, it is interesting to note that most clinical information of the health institution is stored into Oracle databases, which are still largely used in Portuguese health institutions. Nonetheless, MySQL databases are starting to replace increasingly Oracle databases in such environments.

Accordingly, the next six BI clinical indicators were created:

(1) Appointments:

   a. Number of scheduled appointments by year in the past 3 years (2015–2017);
   b. Number of scheduled appointments by year which were not carried out most likely due to forgetfulness, i.e. without prior notice, in the past 3 years (2015–2017).

(2) Surgeries:

   a. Number of scheduled surgeries by year in the past 3 years (2015–2017);
   b. Number of scheduled surgeries by year which were not carried out most likely due to forgetfulness, i.e. without prior notice, in the past 3 years (2015–2017).

(3) Medical Examinations:

   a. Number of scheduled medical examinations by year in the past 3 years (2015–2017);
   b. Number of scheduled medical examinations by year which were not carried out most likely due to forgetfulness, i.e. without prior notice, in the past 3 years (2015–2017).

In order to facilitate the analysis of the indicators, the indicators (a) e (b) were combined for each area i.e. "Appointments", "Surgeries", and "Medical Examinations".

The six BI clinical indicators were built using the Recharts library which is a composable charting library built on ReactJS components [14]. They were added to a simple ReactJS Web page. However, for technical reasons, a copy of the data needed from the Oracle databases were transferred to a MySQL database using the hospital platform for Interoperability, Diffusion and Archive—Agency for Integration, Diffusion and Archive of Medical Information (AIDA) platform. AIDA is a complex system consisting of simple and specialized subsystems, defined as intelligent agents, which are responsible for tasks such as

the communication between heterogeneous systems, the sending and receiving of information, as well as the management and storage of data [15, 16].

Therefore, the indicators were created from the data stored into the MySQL database. The sharing of data between the Web page and the database was performed through RESTful Web APIs in PHP with SQL queries. It is interesting to note that the development of Web content using the ReactJS library is facilitated using MySQL databases when compared to Oracle databases. The sharing of data between ReactJS Web content and data stored into Oracle databases involves making more complex configurations in the development environment, which are not compatible with certain versions of operating systems or even operating systems.

The BI clinical indicators created for each area, namely "Appointments", "Surgeries", and "Medical Examinations", are presented in Figs. 2, 3, and 4, respectively.

After the analysis of the BI clinical indicators in Fig. 2, it was possible to conclude that 4.12% of the scheduled appointments were not realized without prior notice in 2015, 4.24% in 2016, and 5.27% in 2017, for an average of 4.54% between 2015 and 2017.

The indicators represented in Fig. 3 regarding the surgeries allowed to determinate that the percentage of scheduled surgeries that were not realized without prior notice is 8.14% in 2015, 5.79% in 2016, and 5.75% in 2017, for an average of 6.56% in the last 3 years.

Analyzing the BI clinical indicators presented in Fig. 4 permitted to calculate that 8.27% of the scheduled medical examinations were not realized without prior notice in 2015, 5.74% in 2016, and 6.22% in 2017, for an average of 6.74% between 2015 and 2017.

Therefore, it was concluded that too many scheduled appointments, surgeries, and medical examinations were not carried out most likely due to forgetfulness.

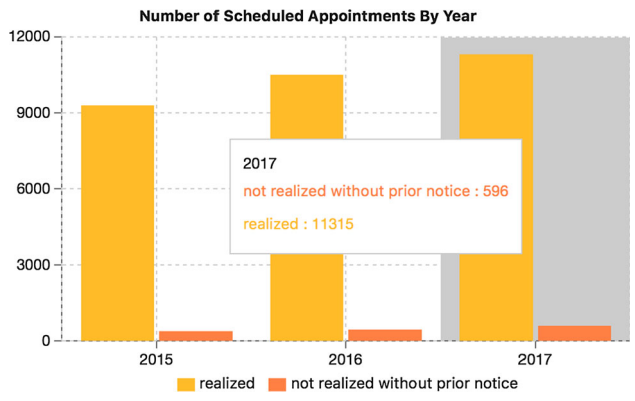

Fig. 2 Business intelligence clinical indicators regarding the number of scheduled appointments from the hospital in the past three years (2015 to 2017): **a** realized (yellow bars) and **b** not realized without prior notice (orange bars) (Color figure online)

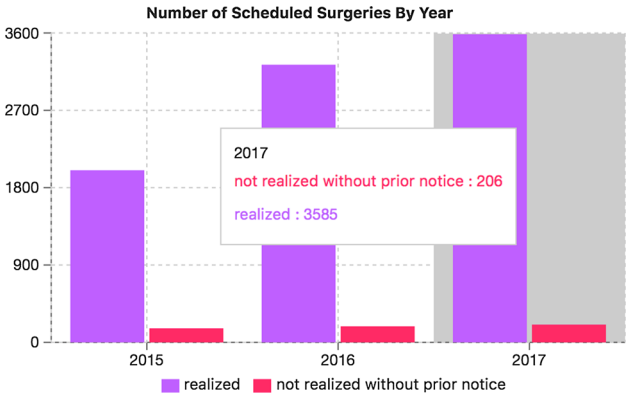

Fig. 3 Business intelligence clinical indicators regarding the number of scheduled surgeries from the hospital in the past three years (2015 to 2017): **a** realized (violet bars) and **b** not realized without prior notice (fuchsia bars) (Color figure online)

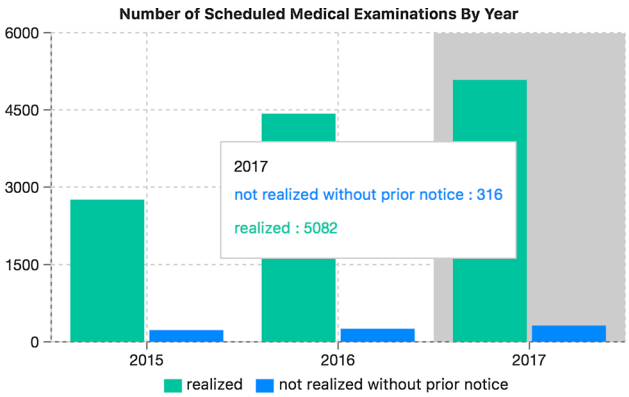

Fig. 4 Business intelligence clinical indicators regarding the number of scheduled medical examinations from the hospital in the past three years (2015 to 2017): **a** realized (green bars) and **b** not realized without prior notice (blue bars) (Color figure online)

Nonetheless, it is important to note that those percentages are perhaps inflated due to unscheduled appointments, surgeries, and medical examinations that were not recorded in the system.

Thus, after confirming the need for a computational tool to warn patients and/or their caregivers and family members regarding their scheduled appointments, surgeries, and medical examinations in order to reduce such numbers—health information and communication technology (ICT) –, the team proceeded to its development at the end of 2017 as described in Subsection 4.2.

4.2 Architecture of the Web application

The main purpose of the Web application is to alert patients and/or their caregivers and family members regarding their scheduled appointments, surgeries, and medical examinations in order to reduce the number of those that were not realized due to forgetfulness. This

situation generated great losses to the Portuguese health institution that mainly included losses of time, human resources, and money.

Therefore, through the computational tool, it is possible to warn them in advance and appropriately via SMS. The default messages built by the Web application using the entered values of the parameters by the users can be customized if needed. On the other hand, the patients can be alerted regarding other situations out those that have already been mentioned, such as warnings about health insurance, a transfer to another health institution or even debt situations, since it enables the insert of new message types by users.

In short, the Web application was developed using the ReactJS library, a JavaScript library, in JSX (a syntax extension to JavaScript) [17]. It is supported by MySQL relational database management system (RDMS) as the backend database. The sharing of data between the Web application and its data warehouse is performed through RESTful Web APIs in PHP with SQL queries. The data stored into the data warehouse include essentially information regarding the users of the Web application and the SMS requests.

Nonetheless, the data related with patients are stored into Oracle databases and are, consequently, supported by the RDMS Oracle DB. The sharing of data between the Web application and those data is executed through SOAP Web APIs in ASP.NET with SQL queries.

On the other hand, the sending of the SMS to patients and/or their caregivers and family members is achieved through back-end processes writing in Python. After the sending of a SMS request via the Web application by a health professional, a new entry is added to the table "SEND_SMS" from the Oracle databases—health information systems (HIS) of the case study. The processes are executed automatically every 5 min in the Oracle databases in order to send SMS based on pending requests—worklist. If the data saved are valid, the SMS is sent to the patient and/or his/her caregivers and family members.

A schematic representation of the workflow of the Web application is illustrated in Fig. 5.

First, the user need to sign into the Web application with its login credentials, which is stored into a production machine (server) in the health institution. By being pervasive, it is distributed to all users connected to the Intranet, that is within the private network of the hospital, and it can be easily accessed through a Web browser.

Then, the user can access the Web application and take advantage of its functionalities. It is divided into five distinct modules, namely:

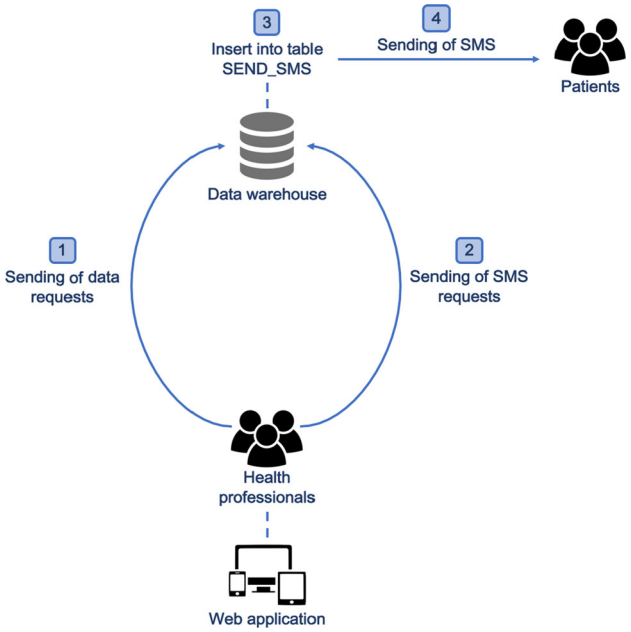

Fig. 5 Schematic representation of the workflow of the Web application

- Dashboard: it is the main module of the Web application. It corresponds to a form where the user must search a patient by its number of process or its number of episode and its number of module. Thereafter, the user chooses the message type of the SMS to be sent and, after its first confirmation, a default message is built using the entered values of the parameters. Nonetheless, the message returned can be customized by the user if needed. After its second confirmation, a SMS request is sent via the Web application as described previously. It also important to note that the mobile phone number associated with the patient returned by the Web services can be edited so that, if needed, more mobile phone numbers can be added or the mobile phone number of the patient can be substituted by the mobile phone number(s) of his/her caregiver(s) and/or family member(s). This is particularly helpful for elderly people;
- Management of Message Types: it enables the management of message types, i.e. the insert, update, and delete of message types;
- Management of Users: it allows the management of users, i.e. the insert, update, and delete of users;
- Number of Weekly SMS Requests: it is a module with a business intelligence (BI) performance indicator regarding the number of SMS requests sent each day in the last week in order to assess its rate of use;
- Help: it is a help module for users to be used if they face some difficulties.

5 Proof of concept

To test the viability, utility, quality, and efficiency of the Web application, a proof of concept (PoC) was necessary, which consisted essentially of a SWOT analysis. It allowed the identification of its strengths, weaknesses, opportunities, and threats.

Regarding the strengths, the following points were identified:

- Warning patients and/or their caregivers and family members via SMS in advance and appropriately;
- Cheaper, faster, and more customizable than sending SMS using a smartphone;
- Reducing the number of appointments, surgeries, and medical examinations that were not carried out most likely due to forgetfulness;
- Decreasing losses concerning time, human resources, and money;
- High usability, i.e. it is an intuitive and user-friendly Web tool;
- High scalability, i.e. it is relatively easy to expand the functionalities of the solution;
- Easily adaptable to different case studies.

On the other hand, its weaknesses were also recognized:

- Requires Intranet connection.

Concerning the opportunities, which correspond to the external factors that could positively influence the solution, the next topics can be outlined:

- Modernization and organizational development in the health institution;
- Increasing expectations of the hospital administration to computerize certain processes;
- Having more clinical data stored into the health information systems (HIS) in order to create other business intelligence (BI) clinical and performance indicators;
- The development of new modules and functionalities;
- The adaption and use of the Web application in more case studies.

Finally, it is possible to highlight the following threats associated with the Web application:

- Patients and/or their caregivers and family members that do not have smartphones to receive SMS;
- The still lack of acceptance to resort to new technologies by many health professionals;
- Potential problems regarding the network connectivity (Intranet).

6 Conclusion and future work

Finally, through this project, business intelligence (BI) clinical indicators were created in order to assess the necessity of a health information and communication technology (ICT) to alert patients and/or their caregivers and family members regarding their scheduled appointments, surgeries, and medical examinations. Those indicators confirmed the need of such solution and, therefore, a Web application was developed to warn them via SMS in advance and appropriately by health professionals of a Portuguese health institution.

As stated throughout this paper, advantages linked with the use of the computational tool include reducing the number of appointments, surgeries, and medical examinations that were not carried out most likely due to forgetfulness, and consequently, decreasing losses concerning time, human resources, and money.

Regarding future work, in the coming years, it is intended to create more BI clinical and performance indicators when more data will be stored into the health information systems (HIS) of the health institution. The indicators that will be created incorporate indicators concerning the scheduled appointments, surgeries, and medical examinations from the hospital that were realized and not realized without prior notice by year. Thereafter, the main goal is to determine if effectively the use of the solution considerably reduces the number of appointments, surgeries, and medical examinations that are not realized. Additionally, an indicator regarding the number of monthly SMS requests by year will be added to the Web application in order to evaluate the rate of its use in more detail. Lastly, it is also foreseen to expand the number of case studies in the coming months.

Acknowledgements This work has been supported by Compete POCI-01-0145- FEDER-007043 and FCT—*Fundação para a Ciência e Tecnologia* within the Project Scope UID/CEC/00319/2013.

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