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Integrating a New Generation of Interoperability Agents into the AIDA Platform

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Abstract. Health is an information rich and complex environment, which makes it essential to implement interoperability in different health organizations and the consequent homogeneity among Health Information Systems (HIS). The Agency for the Integration, Dissemination and Archiving of Medical and Clinical Information (AIDA) is a consistent agent monitoring platform capable of guaranteeing the automation of information as well as the interoperability and integration of HIS. This platform was designed as a solution to the information islands that are commonly found in hospital systems, and it is currently being used in several hospitals throughout Portugal. However, like any technological innovation, the solution requires a constant health technology assessment (HTA) to ensure the absence of obsolescence and a continued efficiency and security of the platform. Hence, this article focuses on the relevance and the need for vigilance, culminating in the restructuring of certain intelligent agents that make up the AIDA platform.

Keywords: Health Information Systems, Interoperability, Obsolescence, Health Technology Assessment.

1. Introduction

In recent times, technological and scientific advances in the field of information have been presented as the main drivers for creating a new era world. The "Information Age" appeared after the "Industrial Age" and accompanies us until today, with continuous growth and valorization of information and technology as well as significant improvements in society's quality of life [1].

Nowadays, with a society that increasingly privileges information, coupled with the growing amount of data produced internally and externally by organizations, it is crucial to accelerate the implementation of Information Systems (IS), capable of responding to problems related to the flow of information [2]. Through these systems, the development and growth of an organization in a market without borders is guaranteed since they enable the storage and manipulation of vital information for decision making [3] [4]. Therefore, for a competitive and profitable advantage, the application of Information Technology (IT) is fundamental, since it covers the set of all solutions and human and/or computational resources that allow access, consultation, management and use of information [5] [6].

In the information society, the binomial IS/IT is used in the most diverse areas and activities of daily life, including the health area. In consequence, the Medical Informatics (MI) emerges with a leadership role in the search and evolution of innovative solutions, capable of guaranteeing quality in decision support and in clinical practice.

Health is a complex environment that is enriched with information from different sources and that needs to be accessed by multiple health professionals at any time and in distinct locations [7]. In this sense, it is through Health Information Systems (HIS) that it is possible to aggregate and process all data and information from the health environment, which, consequently, contribute to the decision-making process and guide the entire process of managing the institution's clinical and administrative information [8]. With the applicability of these information systems, it is possible to guarantee the progress and optimization of clinical processes, quality in the provision of health care, the reduction of costs and clinical errors as well as the increased satisfaction of health professionals and patients [9].

Nevertheless, HIS are usually characterized as complex and consisting of distributed and heterogeneous systems, whose interaction between them and accessibility to them in a timely manner is nowadays fundamental to the success of clinical processes [10][11]. So, it becomes essential to rely on interoperability and its integration at different conceptual levels in order to use HIS capable of cooperating and communicating with each other ensuring, in this way, the sharing and communication of information between all units and health professionals in their hospitals [12].

AIDA is an example of these complex systems, whose main objective is to integrate, disseminate and archive large sets of information from different sources, such as services, departments, units, computers and medical devices, assist medical applications and control the flow of information through a network of intelligent information processing systems with an adjustable level of autonomy [12] [13] [14]. This platform consists of several agents it is important to highlight agent 61 and agent 62, which are responsible for interacting with hospital partners through the exchange of Health Level Seven (HL7) messages. Agent 62 ensures the creation and sending of HL7 messages from AIDA to various partners, whereas agent 61 is responsible for receiving, interpreting, and processing the HL7 messages sent by hospital's partners. The AIDA platform is currently in use in several hospitals across Portugal, including the Centro Hospitalar Universitário do Porto (CHUP), which will serve as the case study for this article.

As the exchange of information between hospital partners and their interpretation are fundamental aspects of hospital operation, it is essential to seek to maximize their performance while reducing the occurrence of errors and inconsistencies. In this sense, the focus of this study is to ensure a successful and efficient communication between the AIDA platform and all the third-party companies involved in the provision of health care within the CHUP. To achieve this goal, the intelligent agents 61 and 62 of AIDA will be carefully assessed and reformulated according to the hospital's needs.

The present paper is organized into five sections. After the Introduction, we provide a Background to contextualize the readers in the topic addressed in this paper with particular emphasis on the concept of Interoperability and the AIDA platform. Subsequently, in section 3, the importance and value of the reformulation of technologies implemented in CHUP hospital units is explained, in order to solve problems of obsolescence and redundancy. Focusing on the impact of the reformulation of agents 61 and 62, responsible for the exchange of information between the different systems of the AIDA platform. Finally, the results achieved with this measure and the main conclusions are presented, as well as some perspectives for future work.

2. Literature Review

2.1. Interoperability

Despite being a term often used today, the meaning of interoperability remains ambiguous and diffuse. In this sense, and in general terms, it is possible to integrate the various definitions found in the scientific literature and characterize the concept

of interoperability as the ability of different systems to communicate and exchange information with each other, and to process and interpret this information correctly [15].

For health, the implementation of interoperability in different health organizations and the consequent homogeneity among HIS guarantees a diversity of benefits. In fact, with the implementation of interoperable IS in the health area, better care and provision of health care is guaranteed and, consequently, a reduction in medical errors, since health professionals have a better access to a range of relevant and reliable information when and where they need [16].

However, the integration of interoperability in a hospital environment proves to be a challenging task, since it is crucial that all information transferred is standardized to avoid different structures and misunderstandings. In this way, for interoperability between HIS, it is essential to use different standards to ensure the normalization of information. These standards can be divided into three distinct purposes: referring to the representation of clinical information (SNOMED-CT), to communication (HL7) and, finally, to the medical image block (DICOM) [12] [17].

Among all these, the HL7 protocol is perhaps the most internationally recognized and defines a set of standard formats that, through a message structure, allows the exchange of information between different heterogeneous hospital applications [5]. Initially, the versions of HL7 were exclusively syntactic, however, nowadays, the most current version (version 3), in addition to defining a syntax for the messages exchanged, seeks to incorporate semantic interoperability, including the appropriate use of information exchanged in the direction of the communication behavior of applications [18].

Although interoperability between systems prove to be a common interest and comprehensive within the scientific community, however, is a complex method that, these days, has not yet achieved a consensus definition and implementation [5].

2.2. AIDA

In order to keep up with technological advances in different hospitals, reduce medical errors and, consequently, improve health care, it is essential to implement a consistent platform agents monitoring able to ensure the automation of information and interoperability and integration of HIS. In this regard, the Artificial Intelligence Group, Department of Informatics, University of Minho, dedicated to the construction of an intelligent and dynamic platform, in partnership with the Centro Hospitalar do Porto (CHUP), with the aim of making interoperable HIS, the AIDA.

The AIDA platform is a complex system that consists of specialized and direct intelligent agents, in charge of tasks such as communication between its various subsystems, sending and receiving information, as well as managing and storing information and responding appropriately to user requests. This system uses several means of integration, including technologies such as Service Oriented Architectures (SOA) and Multi Agent Systems (MAS) to ensure interoperability between hospital subsystems, assuming a central role where it is installed [11, 17, 19].

The success and functioning of AIDA is essential since it is a platform associated with the health area, where a simple mistake can have serious consequences for the health organization and, indirectly, to the health status of different patients.

For this reason, it is essential to guarantee the cooperation between the various intelligent agents and their individual maintenance.

3. Data and Methodology

The development of the present study was based on the Design Science Research (DSR) methodology, which is used in the construction and evaluation of useful and rigorous IT solutions.

DSR is a rigorous process methodology at the level of scientific research and that allows, through the projection of artifacts, professionals to solve observed problems and process information. These resulting artefacts should be viable solutions capable of resolving, in an excellent way, the objectives initially proposed and the problem in question [20, 21, 22].

The model of the DSR methodology, is represented in Figure 1. In a first phase, this methodology identifies the problem and the motivation, as well as defines the objectives of the solution. Then, the artefact is designed and developed, in a rigorous scientific process based on the knowledge and theory previously explored, which implies an initial research that is as enlightening and efficient as possible. In a next step, the solution should be applied to a specific case and, subsequently, evaluated with relevant metrics if the defined objectives have been achieved. Finally, if the assessment is conclusive, the artifact must be communicated to the relevant entities. If the results are not conclusive, the stage of setting objectives is returned, or a new projection of the artifact is carried out [23] [24].

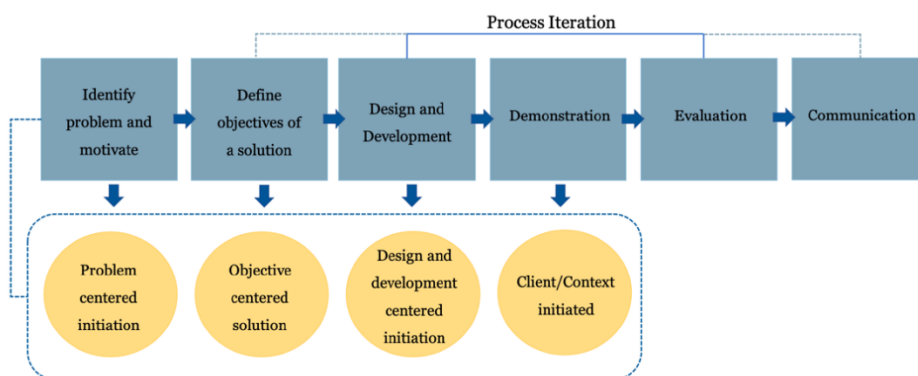


Fig. 2. Model of the DSR Methodology. Adapted from [22, 23].

In the present paper, the case study developed follows the DSR methodology, since, after an analysis of the current state of the technologies implemented in the CHUP hospital units, the presence of obsolescence was detected in certain intelligent agents that make up the AIDA platform.

Following the identification of the problem and resulting motivations (mentioned in the Introduction and earlier in this section), it was proceeded to the definition of the objectives such as the assurance of interoperability and integration between the different systems. After a concrete definition of the problem and objectives, it was possible to restructure these agents and, finally, in a conclusion phase, highlight the added value of the work.

3.1 Problem Identification

Given the constant technological and scientific progress, IS developed and their applications may become obsolete and without the capacity to respond to the needs of an organization. In the IT area, obsolescence is defined as a component or system (hardware or software) that is no longer viable, useful or capable of performing the necessary functions, despite being in perfect working condition [25] [26]. Nowadays, and due to the exponential technological development, the presence of obsolescence in any organization is a frequent concern, especially in organizations such as health institutions.

With the informatization of health care systems comes an increasing risk of technological obsolescence. As health care systems increasingly rely on technology,

the risk of technological obsolescence grows. Despite its significance, its resolution is not always seen as a priority, as it is widely acknowledged that the hospital system is one of the most complex, with a wide range of demands but limited resources. In this regard, hospital administrations are often forced to comply with a tight budget that prioritizes the acquisition of hospital physical resources such as beds, monitors, ventilators, computed tomography (CT) scanners and cutting-edge equipment, as well as innovative medication and treatments. The few remaining financial resources are usually spent on acquiring new software, leaving the maintenance, and updating of already implemented technological solutions to the sidelines.

Despite not being included in the budget as a priority, technological obsolescence is in fact impacting in these institutions. Their presence may affect the minimization of costs and resources and negatively affect the provision of health care and, consequently, the patient's health.

In this sense, the systematic existence of a HTA is essential, through which the system or component is evaluated using different parameters, such as performance, reliability, environmental impact, and cost. The presence of these assessments ensures that the technology remains safe and effective, that the cost-benefit ratio is superior to the integration of an alternative, the provision of health care, and, as a result, the patient's health status [27].

By carefully performing an HTA on different systems, platforms, applications and others present in units of the CHUP, it was identified the need to restructure certain intelligent agents that make up the AIDA platform, in particular, agent 61 and agent 62, in order to avoid their obsolescence and ensure that they continue to respond to the functions assigned to them.

As mentioned earlier, these agents are primarily responsible for the interoperability of the AIDA platform using the HL7 protocol, where agent 62 enables the sending of messages and agent 61 is responsible for the processing of the messages. Failure of one of these agents in the hospital environment can be disastrous because communication with other hospital systems such as Picture Archiving and Communication System (PACS) or Laboratory Information System (LIS) is critical in providing quality health care to patients.

The main issues found in these agents were the fact that they were developed in the Visual Basic (VB) version 6 language and organized in an unstructured and inefficient way where some inconsistencies and redundancies were found. In the next subsection the main objectives to combat these problems will be outlined.

3.2 Solution Purposes

As the identification of the problem and its motivation have already been demonstrated, this section focuses on the definition of the objectives, the second stage of the DSR methodology. In this sense, the main objective of this study is the restructuring of the interoperability agents, not only by updating the software from the VB6 language to Java, in order to eliminate the sources of obsolescence and also to solve some compatibility issues (Java is platform-independent language), but also by removing redundant chunks of code and inconsistencies as well as adopting better approaches in order to eliminate sources of inefficiency and increase the performance of these agents.

So, after defining and clarifying the problem, as well as elucidating the needs and motivations of this study, it was proceeded to the identification of all objectives to fulfill in implementing the solution. These objectives include:

- Study and analysis of the status and functionalities of both agents, with the objective of identifying possible efficiency problems and, consequently, understanding what are the possible areas of intervention;
- Software update according to the hospital's needs, to combat obsolescence in CHUP hospital units;

- Guarantee the interoperability and integration of the different systems, in order to guarantee that the solutions fulfill the requirements for which they were initially developed and, thus, guarantee the effective provision of care.

3.3. Design and Development

In order to follow the technological advances of different hospitals, minimize medical errors and, consequently, improve the health care provided, it is essential to ensure that the AIDA platform is consistent and is able to guarantee the automation of information, interoperability and integration. Thus, and as previously mentioned, it is essential to have a systematic reassessment capable of determining that the technologies used are safe, effective, and economical compared to an alternative.

At the time of the CHUP reassessment, it was determined that the intelligent agents responsible for information exchange and interoperability between HIS through information standardization protocols (HL7) were on the verge of becoming obsolete, and as a result, the software upgrade was identified as an essential need.

For a conscious and efficient software update, it was necessary to analyze the environment in which these agents are implemented as well as the type of structure and responsibilities they presented. Following this careful analysis, it became clear that the software update of these intelligent agents should be from VB6 to the Java language.

The VB programming language is characterized as an event-oriented language with a syntax similar to English, which promotes clarity and legibility of the code. In addition, this language also has an Integrated Development Environment (IDE) that makes it easy to build the interface of any application [28]. This programming language had its last version, version 6.0, developed in 1998, however, since 2008, Microsoft, the company responsible for the development of this language, stopped supporting it [29].

On the other hand, Java is class based and object oriented, and it is designed to have as few implementation dependencies as possible [30]. This programming language shares many resources common to most programming languages in use today and is characterized as a general-purpose language, as it allows programmed content to be able to be executed anywhere, without system dependency [30] [31].

Both programming languages have their advantages and disadvantages. As a result, it was necessary to conduct a thorough analysis and consider all factors in order to make the best decision for software implementation. The presentation of the advantages and disadvantages of both languages are shown in Table 1 [29].

Table 1. Comparison between Java and VB6

	Advantages	Disadvantages
VB6	<ul style="list-style-type: none"> - Event-oriented language - Visual Basic code is easy to migrate to other languages - It has a very fast learning curve 	<ul style="list-style-type: none"> - Not supported by Microsoft since March 2008 - It does not support process handling - Does not warn about certain errors or warnings - Only supported on 32-bit operating systems - Non-multiplatform language
Java	<ul style="list-style-type: none"> - Class-Based and Object-Oriented Language - Multiplatform language - Robust, designed to design very reliable software - Secure - Very fast learning curve 	<ul style="list-style-type: none"> - It can be a slow-running language

Through the analysis of this table, it is possible to conclude that Java presents itself as a more advantageous and efficient programming language than the VB6 language, particularly in a clinical setting, due to its robustness and security. Nevertheless, the main reason for this migration was the fact that Java presents itself as a multiplatform language.

The migration from VB6 to the Java language should take place carefully since these types of programming languages are extremely different. Thus, in order to take advantage of the maximum resources and structure possible, the agents were re-registered.

Reutilization can be very beneficial for a successful conversion capable of meeting all the necessary objectives. In fact, in codes as extensive as these, the reutilization of procedures, code or class modules can guarantee a reduction in effort and conversion time.

In a first step, the current VB6 application was studied to detect the blocks of code that needed to be changed, since it is an event-oriented language that moves to an object-oriented one. Accordingly, inactive, or duplicate code was removed so that there was no waste of time in converting uninteresting and unused code in these agents.

Subsequently, specific syntaxes were excluded since converting to Java would cease to have an effect, such as the ones corresponding to form modules like *FrmConfig*.

In the next step, the global variables declared that were not used were removed, as well as all the functions and subs that were not called in the main code. It is important to note that a function, unlike a sub, is characterized as a code structure capable of returning a certain value.

After carrying out all these changes, the different functions and subs were analyzed in order to find errors, inconsistencies and potential sources of inefficiency. After solving those issues, an attempt was made to optimize the code through the interconnection between functions and/or subs that had similar behavior to avoid repeating common code blocks with only minor variations. This interconnection was, in the great majority possible, through the use of global variables or the addition of certain arguments. In this way, it was possible to considerably reduce the amount of code of these agents as well as to remove some redundancy issues found in the code. Furthermore, the aggregation of similar functions and subs allowed a better code optimization in terms of performance and scalability, as it enabled the creation of a parameterization table within the hospital database. In this way, instead of having to change several functions/subs each time the hospital adopts a new partner, it is only necessary to add a new row in the hospital's database with the parameters of the new partner system.

To ensure interoperability and integration between the different systems, Structured Query Language (SQL) was used, a programming language based on relational algebra and relational calculation, so that, in this way, it was possible to manage the relational database and its manipulation. With this tool, a parameterization table was created for each of these agents, which enabled the connection between the different types of hospital services that exist and the hospital units where AIDA is present. Through this implementation, users of this platform can more easily activate or deactivate certain hospital services in a given health institution.

In a last step, the code was compiled and executed, with the development of different tests to find problems not previously detected and correct them to ensure that both agents worked as expected.

4. Results

The realization of this study allowed the conversion of intelligent agents from CHUP to a newer software, thus ensuring the elimination of the obsolescence problems to which the old software was subjected.

As mentioned in the previous section, it was removed the global variables, functions and subs not declared in the main code and tried to optimize them through the interconnection between functions and/or sub that had characteristics in common. In order to make these changes more visual and demonstrate the significant differences between the initial version of these agents and the one developed, the following graphs were created to present the balance between the initial and the final code. Figure 2 and 3 show the comparison between the number of variables, functions and subs in the initial and final solution for agent 61 and 62, respectively.

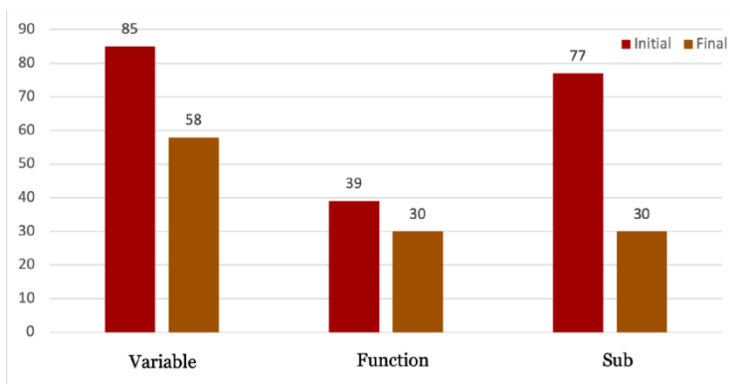


Fig. 3. Balancing of the amount of code between the initial and final version of agent 61.

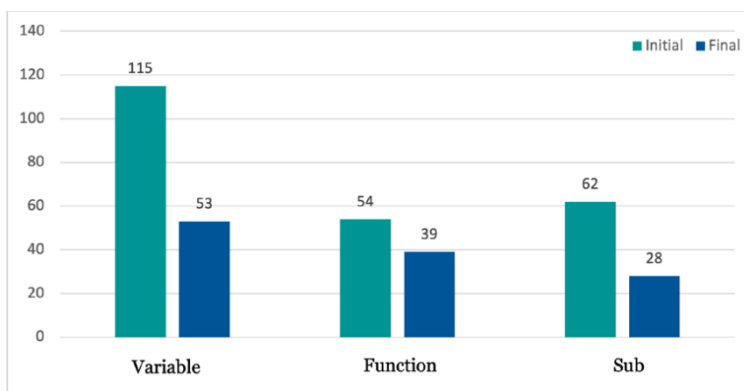


Fig. 4. Balancing of the amount of code between the initial and final version of agent 62.

Through all these measures described and with the analysis of the data presented, it became possible to optimize the agents 61 and 62, making them more agile and effective while still meeting the needs for which they were initially designed. Consistently, the execution of this reformulation of the agents enabled the continuity of hospital services and the avoidance of unnecessary failures, thus promoting quality in decision support and clinical practice.

In the future, it is, therefore, essential to carry out the conversion of all agents that make up the AIDA platform, in order to guarantee the correct functioning of the health care flow allowing health professionals to access the necessary information for clinical decision making and, consequently, providing efficient health care.

5. Conclusion

With the constant technological and scientific advances, the technologies implemented in any organization, such as health institutions, require constant maintenance and progress so that, in this way, they can follow the exponential evolution felt nowadays. In this way, it becomes essential that organizations are able to respond to the needs that arise with this technological progress, such as allowing the correction of errors that arise from the implemented measures, as well as allowing the change of technologies that become obsolete and unable to meet the organization's needs. To this end, the presence of continuous maintenance of an organization's technologies may be the key to success.

In a hospital unit, maintenance and HTA processes ensure that the technology remains safe and effective, that the cost-benefit ratio of the technology is positive, and that the systems are changed before they are even considered obsolete. Thus, the efficiency of the provision of health care and, consequently, the health status of the patient are ensured.

The case study presented in this article made it possible to perceive the need for these reformulations in the health systems of the CHUP units. The analysis and assessment of agents 61 and 62 from the AIDA platform allowed to keep up with the technological advances and to take the best of them, removing potential sources of obsolescence and redundancy problems, and ensuring interoperability and integration between different systems.

Through a positive balance of this implementation, we intend to continue updating the AIDA platform and extend this change to all intelligent agents in the CHUP hospital units. Following a successful implementation in this hospital, the upgraded AIDA platform will be migrated to the remaining hospitals where this platform is being used. In the future, it is also planned to implement an activity and error log record of these agents in a NoSQL database using Elasticsearch because it allows for the storage, search, and analysis of massive volumes of data quickly and in near real-time. It is then intended to perform a visual exploration and analysis of these data using Kibana in order to monitor the behavior of these agents in real time using dashboards, aggregators, and data filtering.

As a result of converting all agents to the Java language and addressing their redundancy and information disorganization issues, obsolescence was completely eliminated from this software, so that compliance is guaranteed in all technological solutions implemented in the CHUP.

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Aims and Objectives

Published online by ICS two times a year, Journal of Digital Science (JDS) is an international peer-reviewed journal which aims at the latest ideas, innovations, trends, experiences and concerns in the field of digital science covering all areas of the scholarly literature of the sciences, social sciences. The main topics currently covered include: Digital Media; Digital Economics, Education, Engineering, Finance, Health Care.

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