# Intelligence in Interoperability with AIDA

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**Abstract.** Healthcare systems have to be addressed in terms of a wide variety of heterogeneous, distributed and ubiquitous systems speaking different languages, integrating medical equipments and customized by different entities, which in turn were set by different people aiming at different goals. Demands of information within the healthcare sector range from clinically valuable patient-specific information to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting. The main goal is to gathering this information and present it in a readable way to physicians. In this work we show how to achieve interoperability in healthcare institutions using AIDA, an interoperability platform developed by researchers from the University of Minho and being used in some major Portuguese hospitals.

**Keywords:** Semantic Interoperability, Ambient Intelligence, Electronic Health Record.

## 1 Introduction

Healthcare systems have been for some years a very attractive domain for Computer Science (CS) researchers. Even more, such systems have great potential for information integration and automation, and this is an issue of study in which medicine and agent-based technologies and methodologies for problem solving may overlap. Furthermore, healthcare systems have to be addressed in terms of a wide variety of heterogeneous, distributed and ubiquitous systems speaking different languages, integrating medical equipment and customized by different entities, which in turn were set by different people aiming at different goals [1].

Demands of information within the healthcare sector range from clinically valuable patient-specific information to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting. Gathering this information and present it in a readable way to physicians it's an interesting task. This lead us to consider the solution to a particular problem, to be part of an integration process

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of different sources of information, using rather different protocols, in terms of an Agency for the Integration, Diffusion and Archive (AIDA) of Medical Information, bringing to the healthcare arena new methodologies for problem solving and knowledge representation, computational models, technologies and tools, which will enable ambient intelligence or ubiquitous computing based practices at the healthcare facilities [2]. With access granted to clinical and historical databases, agent technology may provide answers to those who give assistance to patients in time and medical evidence [3].

Every day new applications are developed to assist physicians on their work and healthcare is turning into a science based on information and reputation. We want to find out how usability is maintained in this new landscape of social and ubiquitous computing, when applied to healthcare units, a domain that presents the strongest social focus, and in this way offering the biggest challenge for socially aware software systems design [4]. Nowadays, the exchange and share of clinical knowledge among medical information systems is an important feature to improve healthcare systems, quality of the diagnosis, but mainly, to improve quality in patient treatment.

Semantic Interoperability and Ambient intelligence are seen in this work as the key to solve this problem. Electronic Semantic Health Record (ESHR) will provide the base for this work. The guarantee of a homogeneous information system in a health care unity will produce enormous benefits to the institution. Reduction in diagnosis and appointments time since information about a patient is available at one time in the same place would give doctors more time to treat patients better. Less medical errors would be expected due to better quality of information [5].

## 2 Interoperability

Nowadays information technologies (ITs) in medicine and healthcare are facing a scenario in which a variety of healthcare providers have introduced ITs in their everyday workflows with a certain degree of independence. This independence may be the cause of difficulty in interoperability between information systems [5]. The overload of information systems within an healthcare facility may lead to problems in accessing the total information needed, since it is hard for a physician to access all information sources in an acceptable period of time. In the last decade, Health Information Systems (HIS) have gained great importance and have grown in quality and in quantity. With this information overload, it is necessary to infer what information is relevant to be registered in the EHR and decision support systems must allow for reasoning on incomplete, ambiguous and uncertain knowledge. Demands of information handling within the healthcare sector range from clinically valuable patient-specific information to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting.

Researchers in the field of Hospital Information Systems have focused special attention to the field of quality of information. A Health Unit is computationally represented by a heterogeneous set of applications that speak different languages and are customized by different customers. So a practical and effective

communication platform between information systems is paramount taking into consideration the quality of information [5].

Each service has small database management systems where specific patient data are registered depending on pathologies or specific interests. This computational tissue generates development problems. However, these applications are used by people with good satisfaction despite they do not allow a transversal vision of the patient data along different services or specialties, they can not grow easily and sometimes they do not attend secure and confident procedures. Running applications in distributed environment is a huge problem when applications have not been developed to share knowledge and actions.

Information Systems capabilities are increasingly exposed and exploited, however, software developers and users must lead with new challenges. The EHR is already a topic widely discussed and explored that has brought innovations and advances every day. However the new requirements are to manage all information that is produced in health facilities to ensure quality and easy exchange between HI. It is necessary to use new emerging technologies.

Interoperability has been rather confined within the realms of IT and technology. Although IT plays a key role in making businesses interact seamlessly, such an information exchange infrastructure is meaningless if the other core aspects of business collaborations are not interoperable. Hence, the concept of Business Interoperability goes beyond IT, into organizational aspects of businesses, and includes the level of people-to-people interactions. Smoother workflows also mean that business processes originating in one organization can seamlessly flow into a collaborating partner organization without getting caught up in bureaucratic red tape. Systems for conflict resolution and Intellectual Property Management can further ensure Business Interoperability.

In the last years many projects have pursued the interoperability of EHR information systems. The different approaches have proposed solutions based on specific standards and technologies in order to satisfy the needs of a particular scenario, but no global interoperability frameworks have been provided so far. Some countries are already planning a unified medical language to ensure that the information is stored according to the same syntax and semantic. The Unified Medical Language System (UMLS) is a project of the US national Library of Medicine (NLM) and provides a conceptual framework for concept categorization. Information access is simple and effective, providing to users information with quality [5].

There are some research groups around the world working on semantic web, including the clinical area. Jentzsch and some colleagues developed a system to support the pharmaceutical area that allows the connection between drugs, treatments, cures and laboratory tests via semantic web. This system shows how to search for a Chinese medicinal herb that met the requirements for patient administration [6]. Jentzsch and his staff show how to build decision support systems in clinical activity. These technologies will be of great interest, requiring only some adaptation in HIS and hospital software providers [6].

### 2.1 Semantic Interoperability

The information to be transferred must be standardized and normalized in order avoid different structures and misinterpretations. We must also take into account the data semantics, so information can be understood by different systems. In addition, the use of standards ensures the best communication between health professionals and interoperability between systems, allowing some automation in the hospital recording. The standards used in EHR are divided into three different purposes:

- standards for representing clinical information;
- communication standards; and
- image standards.

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), Systematized Nomenclature of Medicine-Clinical Terminology (SNOMED-CT) and International Classification for Nursing Practice (ICNP) are standards for classification of diseases and therapeutic clinics, where each therapy or disease is associated with a code recognized anywhere in the world. The use of these standards ensures that the EHR can be readable by any clinician in the world, allowing machines to interpret symptoms and assisting the clinicians in making a diagnosis and treatment plan decision [7]. As communication standards, the AIDA-PCE adopts the Health Level Seven (HL7) as a protocol for exchanging messages, and web architectures and service-oriented architectures (SOA).

There are a high number of benefits of semantic web but there are also some disadvantages. One negative factor is the complexity of implementation and the specific domain of the medical field.

## 3 Ambient Intelligence

Ambient intelligence is related with an atmosphere where rational and emotional intelligence is omnipresent [2]. In an ambient intelligent environment, people are surrounded with networks of embedded intelligent devices to gather and diffuse information around physical places, forming a ubiquitous network around an integrated global middleware accepting specific requests and data from heterogeneous sources, and providing ubiquitous information, communication and services. Intelligent devices are available whenever needed, enabled by simple or effortless interactions, attuned to senses, adaptive to users and contexts, and acting autonomously. High quality information and content may therefore be available to any user, anywhere, at any time, and on any device. Users are aware of their presence and context and digital environments are sensitive, adaptive, and responsive to needs, habits, gestures and emotions [2]. In virtual health care environments, they can not be separated from medical informatics, biomedical informatics or bio-informatics, aggregating electronic health records, decision support, telemedicine, knowledge representation and reasoning, knowledge

discovery and computational biology. Radiological films, pathology slides and laboratory reports can be viewed in remote places. Remote robotics is used in surgery and telemedicine is becoming popular. However applications are used for discrete clinical and medical activities in specific areas and services, in particular diagnostics and pathologies.

Ambient Intelligence benefited from an exponential growth of Internet use on the last few years. New rapid web advancements are emerging, transferring technology benefits sometimes without a solid theoretic underpinning [2]. Although web browsers support many features that facilitate the development of user-friendly applications and allow users to run application anywhere without installing flat software packages in order to run remote applications. Storage and information access over the web encourages the information and knowledge reuse and the offer of global information and resources. The vitality of a web-based system lies in its integration potential, in supporting communities of virtual entities and in the gathering, organization and diffusion of information. Operating on the web means the use of documents or programs that contain images, audios, videos and interactive tools in addition to text. Scripting languages are used to build high level programs improving distribution, as well as information and knowledge sharing, increasing quality software and reducing costs [2].

## 4 Implementation

### 4.1 AIDA Framework

To build systems for real healthcare environments, the infrastructure must meet a range of basic requirements with respect to security, reliability and scaling. With access granted to Clinical and Historical Databases, agent technology may provide answers to those who give assistance to patients with a maximum of quality and medical evidence [8]. Communications are sometimes limited by old infrastructures and new projects collide with financial restrictions and bureaucratic delays. The homogeneity of clinical, medical and administrative systems is not possible due to financial and technical restrictions, as well as functional needs. The solution is to integrate, diffuse and archive this information under a dynamic framework, in order to share this knowledge with every information system that needs it. Indeed, to build systems for real healthcare environments, the infrastructure must meet a range of basic requirements with respect to security, reliability and scaling. With access granted to Clinical and Historical Databases, agent technology may provide answers to those who give assistance to patients with a maximum of quality and medical evidence [9]. Figure 1 shows the schematic representation of AIDA framework. In this schema, it is possible to understand the workflow of information, as well as integration and interoperability.

AIDA is an agency that provides intelligent electronic workers, here called pro-active agents and in charge of tasks such as communicating with the heterogeneous systems, sends and receives information (e.g., medical or clinical reports, images, collections of data, prescriptions), managing and saving the information

and answering to requests, with the necessary resources to their correct and an on time accomplishment [9].

AIDA also supports web-based services to facilitate the direct access to the information and communication facilities set by th1ird parties, i.e., AIDA construction follows the acceptance of simplicity, the conference of the achievement of common goals and the addressing of responsibilities. The main goal is to integrate, diffuse and archive large sets of information from heterogeneous sources (i.e., departments, services, units, computers, medical equipments); AIDA also provides tools in order to implement communication with human beings based on web-based services. Under these presuppositions, a healthcare information system (HIS) will be addressed in terms of Figure 1:

- Administrative Information System (AIS), which intends to represent, manage and archive the administrative information during the episode. Being an episode a collection of all the operations assigned to the patient since the beginning of the treatment until the end;
- The Medical Support Information System (MIS), which intends to represent, manage and archive the clinical information during the episode;
- The Nursing Support Information System (NIS), which intends to represent, manage and archive the nursing information during the episode; and
- The Electronic Medical Record Information System (EMR); and
- The Information Systems (DIS) of all the departments or services, in particular of the laboratories (Labs), Radiological Information System (RIS) and Medical Imaging (PACS - Picture Archive and Communication System), which deals with images in a standard format, the DICOM one.

The architecture presented was envisaged to support medical applications in terms of AIDA and EHR, a form of web spider of an intelligent information processing system, its major subsystems, their functional roles, and the ow of information and control among them, with adjustable autonomy.

Healthcare staff acquires this information and its value is automatically stored and distributed to where it is needed. Every document created within a specialized service respect this rules, making different and individualized departments closer. The coding and ordering features are very useful to link different data to one specific problem, as coded data is much easier to access and it is recommended for decision support using Artificial Intelligence. The electronic ordering embedded in EHR can be used not only to obtain medical equipment or pharmacological prescriptions, but also for acquiring laboratory and imaging studies outside the service where it is used. Furthermore, it may enable the centralization of exam display, allowing different services to share results concerning the same patient, diminishing costs on unnecessary exams, and above all, improving the quality of service being provided [9].

There are also different access permissions when dealing with medical data. Although it can only be viewed by the authorized personnel from any terminal

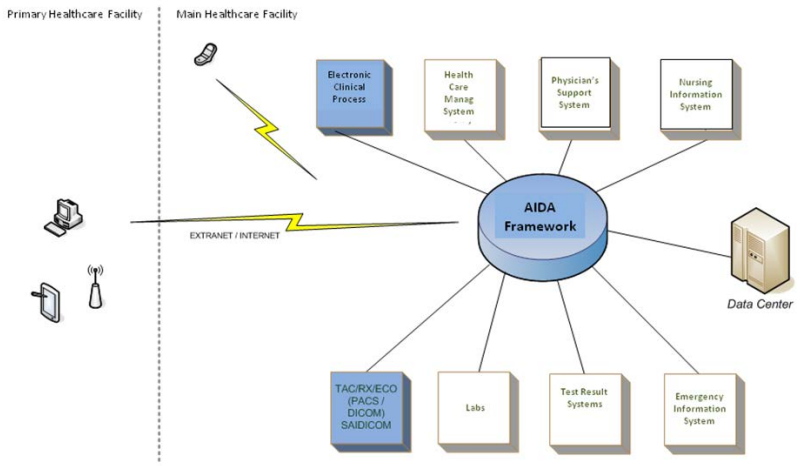


**Fig. 1.** AIDA- Agency for Integration Diffusion and Archive

inside the healthcare facility or even on its own laptop or PDA, the access must be flexible in order to enable the professionals to access it when needed. In other words, the access to the medical information of the patient is as important in terms of privacy as in terms of significance for medical situations. On the other hand, interfaces must be intuitive and easy to use. Messaging enables one to create, send and retrieve messages online. It may be very useful for handling data, images or even file exchange. Encryption and the right protocols of trading are also paramount. Messaging systems are extremely important not only for the internal workflow in a healthcare institution, but as well as an essential component for the development of group work, namely in the area of diagnostic that is supported by decision support systems.

### 4.2 Electronic Semantic Health Record

Adoption of Electronic Health Record (EHR) is well known in several countries all over the world. Canada, Australia, England and United States have already started their own way to achieve an infrastructure for national Health Information Systems [10]. All of these projects share the main elements and focus on the same important subject, interoperability and integration of HIS in spite of interoperability between healthcare providers being a hard task [8]. Unfortunately, information emerges from an assortment of sources, from informatics applications, medical equipments and physicians' knowledge introduced in the Electronic Health Record. Decision support systems are enhanced by quality of information and that can only be achieved with good collection of all the data from the patient. With this information overload, it is necessary to infer what information is relevant to be registered in the EHR and decision support systems must allow for reasoning on incomplete, ambiguous and uncertain knowledge.

Demands of information handling within the healthcare sector range from clinically valuable patient-specific information to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting.

EHR is a repository of information concerning an individual in an electronic format. It is stored and transmitted securely and may be accessed by multiple users [11]. The main objective is to ensure ubiquity, i.e. information is accessible at anytime and anywhere. The lack of integration between the different HIS is not only an obstacle for a more effective clinical practice, but it may lead to a suboptimal care for the patient. Although, this is an accepted definition Hayrinen proved that different researches describe in distinct ways the same thing, and EHR definition is one example [12].

Hayrinen published, in the International Journal of Medical Informatics, an exploratory approach to review the impact of use of the HER as well all the definitions associated with EHR. Hayrinen tries to understand the ongoing studies on several countries and evaluate the possibility of current technologies and underlying architectures and on exploring the health care registers as a source for evidence-based medicine. Automated search was used by the author in several known databases such as PubMed, Cinalh and Cochrane to find recent published works on the area.

In Europe various organizational, institutional, governmental and private initiatives are in course, having the some common main proposes: the standardization, the definition of functional models, minimal data sets and interoperability. EHR depends on three areas:

- Terminology;
- Structure; and
- Interoperability in Communication [13].

Semantic Web has been the subject of much debate and several studies in recent years by the scientific community and the main issue is whether he can fill some gaps in the information systems of health units and perhaps bring an additional quality. W3C consortium is one of the world leading task forces where several research teams gather their work and present it to scientific community in seek for approval and newer approaches for improvements [14].

Several papers come out from this consortium presenting state of the work and tasks executed between publications. Paper derive from explanatory to exploratory and descriptive but the main investigation query and theme is how to use semantic as a mean to achieve full interoperability between systems under the main theme of healthcare.

Jentzsch and colleagues presents the use of semantic as linked data to drugs systems and enabling integration with other web based systems for studies and result retrieving. Their main efforts go to provide the correct drug for the treatment of the patient and study whether their system meets the desired requirements. For the big test for their system they apply it to the search of Chinese herbs that may help in certain diseases. The final results prove that their system is able to provide extended studies for retrieving the correct herb, such as

gene study of the patient, side effects expected and how active ingredients can interfere with patient health [6]. As well as Jentzsch, Clark followed a case study for presenting his work in the Semantic Web in Health Care and Life Sciences Interest Group (HCLS) and the goal is to develop cures for highly complex diseases, such as neurodegenerative disorders, even thought it requires extensive interdisciplinary collaboration and exchange of biomedical information in context. This research team presents the process of integration of semantic ontology in SWAN Alzheimer Knowledge Base. The description provides the user knowledge of ontology that can improve search and connection between systems for extraction of information in easier queries. This project is fully integrated in the Massachusetts General Hospital and provides better access to information relevant for better diagnosis and scientific studies of Alzheimer disease [15].

These studies prove that semantic can promote better results for decision support systems since quality of information is preserved during all processes and correct data is accessed when certain query is performed. Making usage of such technology and combining it with AIDA work methodology an Electronic Semantic Health Record improves quality of information accessed inside the institution. Making a semantic approach to current health records is possible to enhance communication between health care facilities and information can be shared without any lost in quality since queries are most accurate and specific. Semantic enhances linked data and provides the tools to compare data that is most of the time separate but that can together provide accurate information and most important quality information for users. Our main goal is to take semantic advantages and pull out graphical interactions from disperse data.

## 5 Conclusions

This paper presents an innovative intelligent framework responsible for interoperability in healthcare units. The homogeneity of clinical, medical and administrative systems was not possible due to financial and technical restrictions, as well as functional needs. The solution was to integrate, diffuse and archive this information under a dynamic framework, in order to share this knowledge with every information system that needs it.

AIDA platform has, until now, demonstrate to be an useful tool in order to interoperate in a healthcare facility, being used in several portuguese hospitals in Elvas, Portalegre, Guimarães, Pemafiel, Amarante and Oporto. Starting from AIDA, projects in the area of Business Intelligence are now at an ending point. AIDA has shown to be very useful in the process of extracting, loading and transforming info rmation in order to extract knowledge.

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