ARCHETYPE-BASED SEMANTIC INTEROPERABILITY IN HEALTHCARE

Alberto Marques, António Correia, Lúcia Cerqueira
Centro Hospitar do Tâmega e Sousa, Penafiel, Portugal

José Machado, José Neves
Universidade do Minho, Departamento de Informática, Campus de Gualtar, Braga, Portugal

Keywords: Electronic health record, Semantic interoperability, Quality-of-Information.

Abstract: Advances in new Methodologies for Problem Solving and Information Technology enable a fundamental redesign of health care processes based on the use and integration of data and/or knowledge at all levels, in a healthcare environment. Indeed, new communication technologies may support a transition from institution centric to patient-centric based applications, i.e., the health care system is faced with a series of challenges, namely those concerning quality-of-information and the cost-effectiveness of such processes. The distribution of cost-effective health care allowing the patient to take active part in the caring process, provision of evidence-based care on all levels in the system and effective use and reuse of information are key issues for the health care organization. The information and communication technology infrastructure should therefore reflect the view of the health care system as a seamless system where information can flow across organizational and professional borders. Therefore, in this work it will be address key principles that must be at the center of patient-centered technologies for disease management and prevention, namely those referred to above.

1 INTRODUCTION

The areas referred to above share the basic problem of semantic interoperability, which simply means that semantics is preserved in communication between health care providers using different information systems, a circumstance which should be natural but has proven to be very hard to achieve. Consequently, demands of information handling within the health care sector range from clinically valuable, patient-specific information to a variety of aggregation levels for follow-up and statistical and/or quantifiable reporting. A number of protocols are for this purpose put into use in domains such as diagnosis, health dilemmas, interventions, and modus operandi. The context is to assure quality of service at different levels of abstraction, and to agree to process aggregation according to different appearances or perspectives of utilization.

However, almost all existing Electronic Health Record (EHR) systems are built with an explicit domain model, a common approach in current EHR software development practice. This means that the medical domain knowledge present in these system results in higher cost when new requirements in clinical practices occur. If a research program requires a large amount of data to be collected from different clinical sites using dissimilar EHR systems, this make it much more difficult to add a specific feature so the collected data will be comparable. Indeed, the lack of integration between the different EHR systems is not only an obstacle for a more effective clinical practice and research, but it is also a fact that may lead to a suboptimal care for the individual patient, including potential safety problems and an unnecessary waste of resources. Therefore, the new systems should be able to record data both from clinical routine documentation and experimental studies. The users should not be forced to duplicate the data that already might exist in others different information systems in use at the organization.

On the other hand, the users should be able to link the defined data item to an external terminology, which later can be utilized for possible data aggregation and classification purposes. More importantly, such definitions should be shared and reused by other

Marques A., Correia A., Cerqueira L., Machado J. and Neves J. (2010).
ARCHETYPE-BASED SEMANTIC INTEROPERABILITY IN HEALTHCARE.
In *Proceedings of the 2nd International Conference on Agents and Artificial Intelligence - Agents*, pages 305-308
DOI: 10.5220/0002722303050308

users than the original author for data recording, so that the semantics and the quality of service of the data collected from different information systems can be maintained.

2 AGENT ORIENTED PROGRAMMING

Although there is no universally accepted definition of agent, in this work such an entity is to be understood as a computing artefact, being used in hardware or software devices, that exhibit the properties of autonomy, reactivity, pro-activity and social behaviour. To develop such systems, a standard specification method is required, and it is believed that one of the keyfactors for its wide acceptance is simplicity. Indeed, the use of intelligent agents to simulate human decision making in the medical arena offers the potential to set an appropriate software development and analysis practice and design methodology that do not distinguish between agent and human, until implementation.

Agents in a health care facility configure applications or utilities that collect information about the assets in the organization (Alves et al., 2005). Once that information has been collected it can be posted directly to other entities (e.g. a physician), or a server, saved in a file or emailed to someone to be handled at a later date, or sent using HL7 (Health Level 7)[1] or web services in a Service Oriented Architecture (SOA). Indeed, HL7 plays an essential role in extending the interoperability for the development of health information exchange, in the standardization of XML medical document structures and in the specification of robust vocabulary definitions for use in clinical messages and documents (e.g., SNOMED CT), [2] enabling functional specifications for the EHR[3].

3 AIDA

In order to fulfil this goal it was designed and developed an Agency for the Integration, Difusion, and Arquive (AIDA), which allows to interoperate with different information systems at the organization or area levels. The agency conceptually consists of 9

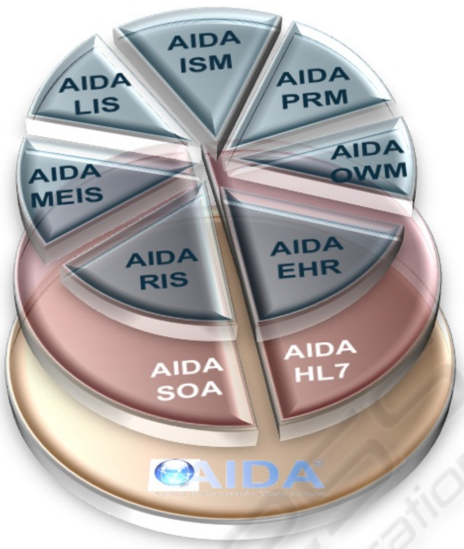

Figure 1: The AIDA Architecture.

(nine) agent based subsystems: AIDA-RIS - Radiological Information System; AIDA-MEIS - Medical Exams Information System; AIDA-LIS - Laboratories Information System; AIDA-ISM - Information System for Monitoring (e.g., vital signals monitoring); AIDA-PRM - Patient Relationship Management (including communication using SMS); AIDA-OWM - Organizartion and Work Management (Including agenda, scheduling, planning and resource management; AIDA-EHR- Electronic Health Records; AIDA-HL7 - Interoperation of systems; and AIDA-SOA - Service Oriented Architecture; where the organization data (e.g. patient data) is stored and managed (Figure 1). These nine subsystems are communicating using web services, in terms of HL7 or XML based messages. The definition of attributes and templates can be shared among different healthcare units having separate information systems. AIDA supports Web based services (AIDA-SOA) to facilitate the direct access to the information and communication facilities set by the humans, i.e. AIDA construction follows the acceptance of simplicity, the conference of the achievement of common goals and the addressing of responsibilities. Indeed, the main goal is to integrate, diffuse and archive large sets of information from heterogeneous sources (departments, services, units, computers, medical equipments). Under these pressuppositions, a Healthcare Information System (HIS) will be addressed in terms of (Figure 1). This system is also now a reality in some major portuguese hospitals, being developed and configured from generated forms of the EHR and sharing information through AIDA.

This system is also now a reality in some major

[1]http://www.hl7.org

[2]http://www.ihtsdo.org/

[3]AIDA-EHR is a portuguese EHR developed at Centro Hospitalar do Porto and based in Problem Oriented Medical Record methodology (Weed, 1969).

portuguese hospitals, being developed and configured from generated forms of the EHR and sharing information through AIDA ((Rigor et al., 2008)). Another interesting application of ubiquitous intelligent systems is described in ((Costa et al., 2007)). EHR and AIDA are the starting point for the creation of Ambient Assisted Living practices on an ubiquitous computational environment for improving the quality-of-life of the elderly, being the core system for AIDA-CI Clinical Inteliigence and Decison Support and AIDA-IA - Ambient Intelligence.

4 THE COMPUTATIONAL MODEL

With respect to the computational model, and in order to fulfil all the pre-requisites associated to Agent Oriented Programming (AOP) stated above, it were considered extended logic programs with two kinds of negation, classical negation, $\neg$, and default negation, *not*. Intuitively, *not p* is true whenever there is no reason to believe p, whereas $\neg p$ requires a proof of the negated literal. An extended logic program (program, for short) is a finite collection of rules and integrity constraints, standing for all their ground instances, and is given in the form:

$p \leftarrow p_1 \wedge \ldots \wedge p_n \wedge not q_1 \wedge \ldots \wedge not q_m$; and

$?p_1 \wedge \ldots \wedge p_n \wedge not q_1 \wedge \ldots \wedge not q_m, (n, m \geq 0)$

where ? is a domain atom denoting falsity, the p_i, q_j, and p are classical ground literals, i.e. either positive atoms or atoms preceded by the classical negation sign $\neg$ (Neves et al., 2007). Every program is associated with a set of abducibles. Abducibles can be seen as hypotheses that provide possible solutions or explanations of given queries, being given here in the form of exceptions to the extensions of the predicates that make the program (Neves, 1984).

These extended logic programs or theories stand for the agents (or programs) that populate the universe of discourse. On the other hand, logic programming enables an evolving agent to predict in advance its possible future states and to make a preference. This computational paradigm is particularly advantageous since it can be used in program synthesis, employing the methodologies for problem solving that benefit from abducibles, in order to make and preserve abductive hypotheses (Kakas et al., 1998)(Kowalski, 2006).

In order to accomplish such goal, i.e., to model the universe of discourse in a changing environment, the breeding and executable computer programs (or agents) will be ordered in terms of the quality of service that stems out of them, when subject to a process of conceptual blending (Turner and Fauconnier, 1995). In blending, the structure or extension of two or more predicates is projected to a separate blended space, which inherits a partial structure from the inputs, and has an emergent structure of its own. Meaning is not compositional in the usual sense, and blending operates to produce understandings of composite functions or predicates, the conceptual domain, i.e., a conceptual domain has a basic structure of entities and relations at a high level of generality (e.g., the conceptual domain for journey has roles for traveler, path, origin, destination). In our work we will follow the normal view of conceptual metaphor, i.e., metaphor will carry structure from one conceptual domain (the source) to another (the target) directly (Figure 2). In Figure 2 INPUT denote the agents (or programs) that are object of optimization and correlative evolution.

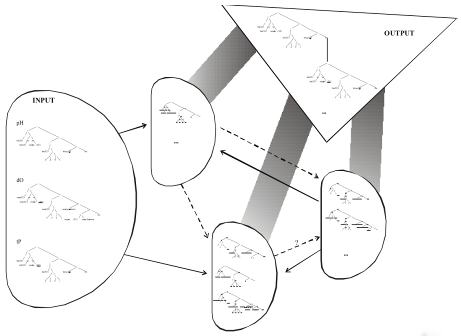

Figure 2: A blended of the agents that make the Universe of Discourse.

We construct a dynamic virtual world of complex and interacting population of agents, entities that are built as evolutionary logic programs or theories that compete against one another in a rigorous selection regime, in order to produce the optimal model to a particular problem(i.e., the OUTPUT, Figure 2). In other words, the agents or logical theories evolve in order to model the universe of discourse, in which fitness is judged by one criterion alone, the quality of service (Analide et al., 2008).

It is now possible to measure or quantify the quality of service, which is given in terms of the logic program or theory, defined at meta-level, according to the logic program (or agent) given below:

$\{\neg qos(Agent, Q_{service}) \leftarrow$
not $qos(Agent, Q_{service}) \wedge$
not $exception_{qos}(Agent, Q_{service})$,
$exception_{pa}(ag_{pa}, 0.5)$,
$exception_{pa}(ag_{pa}, 0.33)$,
$?(((pa(ag_{pa}, X) \vee$

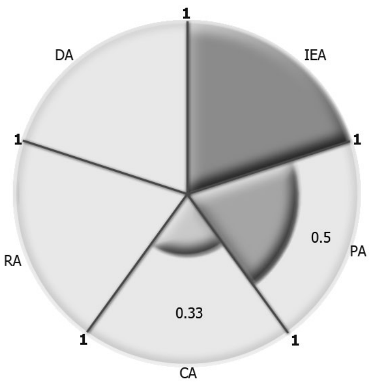

Figure 3: Quality of service reported by the qos agent for the Healthcare Information System.

$$
\begin{aligned}
&\quad pa(ag_{pa}, Y) \wedge \\
&\quad \neg((pa(ag_{pa}, X) \wedge \\
&\quad pa(ag_{pa}, Y))), \\
&exception_{pa}(X,Y) \leftarrow da(ag_{pa}, Y), \\
&da(ag_{da}, da), \\
&ca(ag_{ca}, 1), \\
&\ldots\}_{qosagent}
\end{aligned}
$$

where the integrity constraint or invariant for ag_{pa} stated above denotes an exclusive or, i.e., the quality of service associated with the ag_{pa} is tailored by the exceptions referred to above for ag_{pa} (in this case the value of 0.5). Therefore, the quality of service reported by the *qosagent* for the Healthcare Information System is given by the dashed area of the Figure 3, where *pa*, *da*, *ca*, *ra* and *iea* are respectively predicates for evaluating the quality of service of proxy agents, decision agents, computing agents, resource agents and interaction and explanation agents.

5 CONCLUSIONS

This work presents ongoing research and some developments on improving semantic interoperability of different information systems, using open archetypes. It was introduced an archetype-based agency-independent testing framework, the agency AIDA, that can validate archetype implementations and help ensure quality of service and interoperability of singular information systems. Challenges for integrating archetype and terminology was discussed and a candidate open language for expressing terminological value sets was presented. Finally, advanced archetype-based data sharing using clinically meaningful scenarios was demonstrated. The aim was not only to view the exchanged data but also utilized the archetype semantics of the data. The scenarios included the use of local decision support rules on received data, namely drug interactions and warnings.

REFERENCES

Alves, V., Machado, J., Abelha, A., and Neves, J. (2005). Agent based decision support systems in medicine. In *WSEAS on Biology and Biomedicine, Issue 2, Volume 2*.

Analide, C., Abelha, A., Machado, J., and Neves, J. (2008). An agent based approach to the selection dilemma in cbr. In Badica, C., Mangioni, G., Carchiolo, V., and Burdescu, D. D., editors, *IDC*, volume 162 of *Studies in Computational Intelligence*, pages 35–44. Springer.

Costa, R., Neves, J., Novais, P., Machado, J., Lima, L., and Alberto, C. (2007). Intelligent mixed reality for the creation of ambient assisted living. In Neves, J., Santos, M., and Machado, J., editors, *Progress in Artificial Intelligence*, volume 4874. LNAI, Springer.

Kakas, A., Kowalski, R., and Toni, F. (1998). The role of abduction in logic programming. In Gabbay, D., Hogger, C., and Robinson, J., editors, *Handbook of logic in Artificial Intelligence and Logic Programming*, volume 5, pages 235–324. Oxford University Press.

Kowalski, R. (2006). The logical way to be artificially intelligent. In Toni, F. and Torroni, P., editors, *Proceedings of CLIMA VI*. LNAI, Springer Verlag.

Neves, J. (1984). A logic interpreter to handle time and negation in logic databases. In *Proceedings of ACM 1984 Annual Conference, San Francisco, USA*.

Neves, J., Machado, J., Analide, C., Abelha, A., and Brito, L. (2007). The halt condition in genetic programming. In Neves, J., Santos, M. F., and Machado, J., editors, *EPIA Workshops*, volume 4874 of *Lecture Notes in Computer Science*, pages 160–169. Springer.

Rigor, H., Machado, J., Abelha, A., Neves, J., and Alberto, C. (2008). A web-based system to reduce the nosocomial infection impact in healtcare units. In Cordeiro, J., Filipe, J., and Hammoudi, S., editors, *WEBIST (1)*, pages 264–268. INSTICC Press.

Turner, M. and Fauconnier, G. (1995). Conceptual integration and formal expression. In Johnson, M., editor, *Journal of Metaphor and Symbolic Activity*, volume 10.

Weed, L. (1969). Medical records, medical education, and patient care. the problem-oriented record as a basic tool.