AN AGENT-BASED ARCHITECTURE FOR CANCER STAGING

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Keywords: Group Decision Support Systems, Artificial Intelligence and Medicine.

Abstract: Cancer staging is the process by which physicians evaluate the spread of cancer. This is important, once in a good cancer staging system, the stage of disease helps to determine prognosis and assists in selecting therapies. A combination of physical examination, blood tests, and medical imaging is used to determine the clinical stage; if tissue is obtained via biopsy or surgery, examination of the tissue under a microscope can provide pathologic staging. On the other hand, good patient education may help to reduce health service costs and improve the quality of life of people with chronic or terminal conditions. In this paper it is endorsed a theoretical based model to support the provision of computer based information on cancer patients, and the computational techniques used to implement it. One's goal is to develop an interactive agent based computational system which may provide physicians with the right information, on time, that is adapted to the situation and process-based aspects of the patients's illness and treatment.

1 INTRODUCTION

A healthcare unit may be approached as a distributed computational environment, where different services (here conceived as agents or multi-agent systems), and people, need to communicate, exchanging data and knowledge (e.g., cirurgical experiencies). Indeed, whenever one is faced with a problem, the use of a multidisciplinary team presents in itself as a solution for the extension and complexity of the intersecting medical specifies. Such a team, acting as a group decision supported one, built on the base of human beings and software agents, will intertwine all healthcare related areas. Its role will be crucial on the emulation of expert behavior and to ease of the intricacy of the diagnose process.

The explained architecture depends on the development of key cornerstones which make the system possible and with meaning, once a scheduled system has no utility in a distributed environment. First of all, in an healthcare unit one cannot allow the heterogeneity of the methodologies for problem solving and procedurals inherent to each medical speciality act to disturb the flow of data and information among the different partners. Therefore, a platform for integration, archiving and diffusing of information is required, making all resources accessible to everyone and from elsewhere in the environment, while not requiring any considerable alteration of any of the medical area specificities. The next phase on the development of the architecture referred to above is concerned with the use of web based interfaces as means towards homogeneity and platform independency when storing, accessing, communicating and displaying medical information. The Electronic Health Record (EHR) is such an application which presents the information of the patient according to their particular problems and manages the front-end interaction and inputs with the specific end-user (e.g., physician, nurse, auxiliary personnel). The modularity inherent to the mentioned EHR interface is essential in order to properly integrate and establish a Group Decision Support System (GDSS), enabling workflows, scheduling and structured patient information, leading towards a better quality of service. The integration platform as well as the GDSS architecture considered in this work are designed based on an agent or multi-agent based approach to problem solving, taking into consideration not only the intricacy and heterogeneity of both healthcare software solutions and human interaction, but also the scalability and integration of different technologies and methodologies for problem solving.

Due to the arising need for such an environment

Miranda M., Abelha A., Santos M., Machado J. and Neves J. (2009).
AN AGENT-BASED ARCHITECTURE FOR CANCER STAGING.
In *Proceedings of the 11th International Conference on Enterprise Information Systems - Artificial Intelligence and Decision Support Systems*, pages 313-316
DOI: 10.5220/0001863503130316

in cancer staging, the intricacy of the staging itself, and the fact that it is usually performed by none experts in the area cancer, staging was the chosen field to start implementing such an architecture. The proposed architecture is in production at an healthcare unit and stands as a stepping-stone influence process towards a platform which will allow distinct and technology independent decision support systems to be fully adapted to the healthcare environment through the use of EHR technologies.

It was under this assumption that an Agency for the Integration, Archive and Diffusion of Medical Information (AIDA) was developed, using new computational paradigms and methodologies for problem solving, which have been based based on the concept of agent (Machado et al., 2008).

2 THE AJCC STAGING NORM

In information sharing, an understanding of the concepts and vocabulary involved is paramount. Analogously, in a healthcare environment, a firm knowledge on specialized areas and their uniform lexicon is required, from physicians and other staff, in order to normalize information communication and the process of their dissemination among healthcare units, in performing a group decision meeting, or even on a peers exchange on routine practices, where the existence of different thesaurus associated to particular backgrounds may result in dubious or mistaken assumptions and culminate in misjudgments with complex complications. For this reasons, several thesaurus have been created, trying to establish an uniform syntactic and semantic indexation of medical information, such as SNOMED CT or even more specific normalization, like the American Joint Commission on cancer staging norms (Andrews et al., 2008). This norm consists of a structure of uniform staging variables within every area where there may be cancer, keeping however many specialized variables on specific cancer areas (Greene et al., 1998). The specificity of the staging of each particular area increases the difficulty of following this normalization without any kind of help or, at least, any mean of consultation. Furthermore, case specific information or more detailed information not presented on the form itself, but presented in other sources, may be of great importance for a better understanding and compliancy of the norm defined by the AJCC (Greene et al., 2003).

3 AN IMPLEMENTATION OF A HEALTHCARE GROUP DECISION SUPPORT SYSTEM

The system was developed with prospects of future implementation in a particular healthcare environment. This fact greatly affected the design and software used, resulting in a custom tool, for this specific healthcare environment. Moreover, its adaptability towards the necessities of this particular institution and its already well designed information system, greatly enriched the tool, giving it a broader applicability when integrated with services, while at the same time enabling a seamless area adapted service. In the design of this system, a multi-layer architecture was used in order to increase its reliability and scalability, as well as to improve the results in providing the final service as a whole, i.e., enabling a fully working group decision platform.

In a more specific description, the GDSS follows a client-server hierarchy and can be decomposed into four individual layers (Figure 1). The database layer, the cornerstone of this implementation, is the one responsible for the messaging system, which allow the communication between human agents and software based ones. As well as this role, it is responsible for containing structured information for the agents to extract and analyze. At the present time, it stores information concerning the AJCC cancer staging system, being this informations structured in areas and staging variables. The application server and the user layer are responsible for the web interface available to human agents. The users, through web browsers, and mediated by software agents, converse and negotiate with other agents (human or software ones) that are able to help the user in a particular area of interest or related with the problem. This communication is achieved through conveyed messages between users and agents, stored and managed by relational databases.

Holding the software agents, the agent layer includes several types of services that go beyond system management, being able to interact with both human and software agents, as well as integrating the GDSS with the already established information system of the healthcare institution. The human agents can communicate among themselves or even with other agent systems as long as the other layers are still functional. Within the agent system platform, each agent responsible for interaction with human agents has an individual role and can interact with the user through the messaging system, answering questions and establishing a dialogue aimed towards the problem solution.

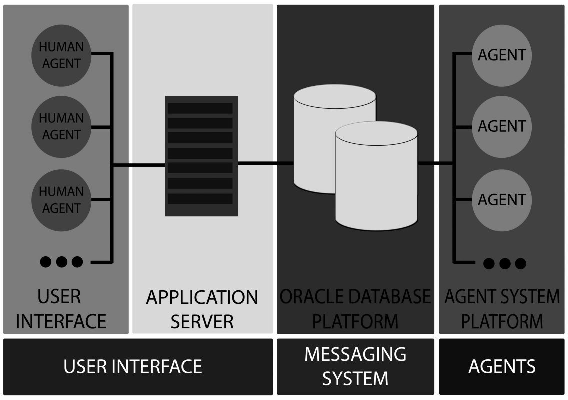

Figure 1: The GDSS Architecture.

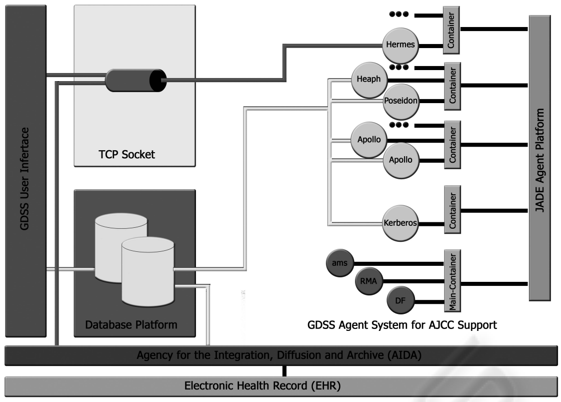

Figure 2: GDSS Integration Platform.

3.1 The User Interface

The user interface is a web application that is both based on Asynchronous Javascript and XML (AJAX) and Hypertext Preprocessor (PHP). With the use of AJAX, the human agent is faced with a much more interactive environment similar to usual desktop applications, where events and other variables can be updated on request or need without full page refresh.

The use of area specific or case specific chat rooms is extremely important in this implementation, as it has a vital role in enabling a specialized group decision platform. In these rooms, physicians and other healthcare personal can discuss matters, being mediated or not, depending of its specific objective. The GDSS has a great potential when integrated within a healthcare facility, not only just with the possibility of intercommunication within this institution on simple work related subjects, just like any intern messaging system, but as well as a mean of storing and easy sharing of information provided by both human and software agents. In this specific case users have a fully functional and user friendly platform with which they can actively interact with the information system itself through software agents.

The GDSS system is as well integrated with the web application used by the same institution to access the Electronic Health Record (EHR). In this way agents, both human and software can generate events when intending to interact with an user when he/she is in any of the interface systems. As a result the system can widely interact with users and be fully integrated with the institutions information infrastructure. Other functions played by other agent systems can be added into this architecture fulfilling the continuous need to scalability within this system.

3.2 Agent System

The problem addressed in this agent based system is concerned with the AJCC's cancer staging forms, more concretely with the intricacy it presents to non oncologist when staging a cancer. The need for a specialized agent may guide a physician in solving a particular staging problem, supporting the decision making process and presenting the final staging score in a normalized form, and then integrated it with the EHR of the patient, make the difference and set our goals. Indeed, the agents share decision support procedures and resulting intents, presenting themselves as the solution for the complex proceedings that may occur at the institutional level.

In the GDSS, agent system interaction with human agents is based mainly on messages sent by means of the database platform; there exists, however, communication agents listening at specific ports using socket connections that can receive information directly from an auxiliary interface. From a brief conversation with the user, a best fitted agent is called in order to successfully help in solving the presented problem. The data respective to cancer staging was extracted from the forms, and the supplementary guidance presented by other AJCC releases explaining the norm(Greene et al., 1998) (Greene et al., 2003). There exists 45 forms out of the 48 chapters of the AJJC norm, being the data in each form represented in different relations of the relational database, distinguishing each staging variable and the relevant information involved in the staging procedure.

3.3 The Technology

Among the possible tools to the analysis and development of our system, the JADE framework (Java Agent DEvelopment Framework) stands as a promisingly one for GDSS. Once it was developed on top of the cross-platform technology Java, allows for a strong connection among two similar computational paradigms, such as The Agent and The Object Oriented Programming ones, as well as the possibility to easily integrate the rich Java libraries into the agent's behaviours. However, developed under an object oriented paradigm, the difference between objects and agents is fully secured in JADE, so that agents can have the autonomy to choose their own actions and react according to their inherent behaviour(Bellifemine et al., 2007).

JADE is according to FIPA (Foundation for Intelligent Physical Agents) specifications, allowing for a standard communication procedure, which can be used to interact with other FIPA compliant agent systems. With JADE, different performatives associated with the intent on the interaction are easily differentiated, allowing for a better comprehension of the communication contents and objective by the agent(Bellifemine and Rimassa, 2001). In the development of a MAS, in order to be able to communicate in a rich manner, presents a potential normalized infrastructure of openness, autonomy, robustness, scaleability and flexibility(Charlton et al., 2000). The coordination among agents was successfully implemented following this norm, though when integrating with the institutions proprietary agent systems, the HL7 norm was used in order to ensure that both platforms were compliant with the same standard(Machado et al., 2008).

4 CONCLUSIONS

Modern science utilizes some basic approaches to the study of how nature works, namely Observational Science, Experimental Science, Theoretical Science, and Computational Science. However, Computational Science is the newest, made possible by the tremendous improvements in both computer hardware and software over the past thirty years. Computational Science, sometimes known as Modeling and Simulation or Scientific Computing, is used in Medicine, and benefits from knowledge in a large amount or scale. On the other hand, staging, a key word in our work, refers to a clinical process that is based on knowledge and on the way cancer develops, with some staging systems covering different types of cancer, when others focus on a particular type of cancer (e.g., distinctive staging systems are used for countless cancers of the blood or bone marrow such as lymphoma). Indeed, doctors gather dissimilar types of information about cancer to determine its stage. The various tests used for staging depend on the type of cancer, and may include physical exams, imaging tests (e.g., XR, CT or MRI), laboratory tests (e.g., blood, urine, uids or tissues), or pathology and surgical reports, i.e., in terms of the algorithm, in Computational Science, the scientific problem must be expressed mathematically, known as the Algorithm. In terms of the architecture, once a suitable algorithm has been determined, that algorithm is translated into one or more computer programs and implemented on one or more types of hardware. In our work, the combination of software and hardware is referred to as the Computational Architecture, the AIDA agency referred to above.

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