49

AMBIENT INTELLIGENCE AND SIMULATION IN HEALTH CARE VIRTUAL SCENARIOS

António Abelha1, Cesar Analide1, José Machado1, José Neves1, Manuel Santos2 and Paulo Novais[1]

[1]*Departamento de Informática, Universidade do Minho, Braga, PORTUGAL*
{abelha,analide,jmac,jneves, pjon}@di.uminho.pt
[2]*Departamento de Sistemas de Informação, Universidade do Minho, Guimarães, PORTUGAL*
mfs@dsi.uminho.pt

The success of change depends greatly on the ability to respond to human needs and to bridge the gap between humans and machines, and understanding the environment. With such experience, in addition to extensive practice in managing change, knowledge sharing and innovation, it would be interesting in offering a contribution by facilitating a dialogue, knowledge café (i.e. bringing in knowledge) on these issues, and how to apply them to new and altering scenarios. When one comes into the area of health care, one major limitation felt by those institutions is in the selection process of physicians to undertake a specific task, where there is a lack of objective, of validated measures of human performance. Indeed, objective measures are necessary if simulators are to be used to evaluate the skills and training of medical practitioners and teams or to evaluate the impact of new processes or equipment design on the overall system performance. In this paper it will be presented a logical theory of Situation Awareness (SA) and discusses the methods required for developing an objective measure of SA within the context of a simulated medical environment, as the one referred to above. Analysis and interpretation of SA data for both individual and team performance in health care are presented.

1 INTRODUCTION

Heath Care Virtual Scenarios (HCVS) allows healthcare workers and professionals to undertake simulated medical practices for patient care, providing a projection of a real unit, using computerized tools to resolve health problems from physical attributes, and simulating conversational dialogue in the area of Medicine. The HCVS offer a wide digital library of cases under supervision allowing the attendance of medical and nursing education courses, in particular in the intensive care arena, integrating highly heterogeneous sources of information into a coherent knowledge base. The system content is created automatically by the physicians as their daily work goes on and students are encouraged to articulate lengthier answers that exhibit deep reasoning, rather than to deliver straight tips of shallow knowledge. The goal is to take advantage of the normal functioning of health care units to build on the fly a knowledge base of cases and data for teaching and research purposes.

Medical simulation facilitates the widespread acceptance of new techniques in health units and allows the participants to practice diagnosis, medical management and behavioural approaches, with no risk to patient safety. Simulation is a practice where conditions or hypotheses are created in order to study or experience real situations or actions. Learning includes observation (e.g., video watching or book reading), verification (e.g., the accuracy of some information or looking for clues), searching of hypotheses (e.g., diagnostic), induction of rules (e.g., program generation) and problem solving (e.g., deduction). Learning may be built upon a web-based framework and involves lessons or tutorials. Students work on a context-dependent scenario activating a precipitating event and requiring a fast response, and play with possibilities and alternatives making the approximation between simulation and game. In the HCVS, learning should arise from how people learn, naturally.

Beyond the organizational, functional, technical and scientific requisites, it must be taken into consideration ethical and legal issues, as well as data quality, information security, access control and privacy. Indeed, in a HCVS, the collection of vast amounts of medical data will not only support the requirements of archiving but also provide a platform for the application of data mining and knowledge discovery to determine possible medical trends and the real data to support educational training. Knowledge discovery techniques can be applied to identify pathologies and disease trends. The data can also be used for educational and training purposes because maybe one of the unique cases can be identified and used in expert system like applications to advise practitioners.

On the other hand Ambient Intelligence (AmI) is a new paradigm in information technology, in which people are empowered through a digital environment that is aware of their presence and context, which is sensitive, adaptive, and responsive to their needs, habits, gestures and emotions [1]. Indeed, simulators are used to evaluate the skills and training of medical practitioners and teams or to evaluate the impact of new processes or equipment design on the overall system performance.

2 MEDICAL INFORMATION SYSTEMS

Specific interaction and communication based protocols are paramount for the successful implementation, running, and/or management of any medical information system. Indeed, Medical Information Systems have to be addressed in terms of a wide variety of heterogeneous distributed systems speaking different languages, integrating medical equipment and customized by several companies, which in turn were developed by people aiming at different goals. This lead us to consider the solution(s) to a particular problem, to be part of an integration process of different sources of information, using different protocols, in terms of an Agency for the Integration, Diffusion and Archive (AIDA) of medical information, and the Electronic Medical Record (EMR) software, bringing to the healthcare arena new methodologies for problem solving in medical education, computational models, technologies and tools.

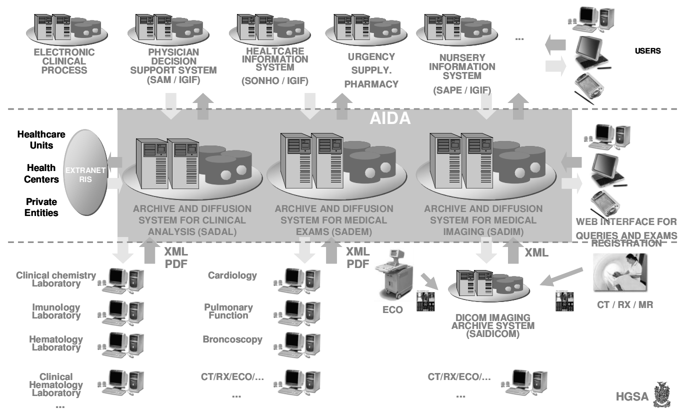

Figure 1 - AIDA – Agency for Integration, Diffusion and Archive of Medical Information

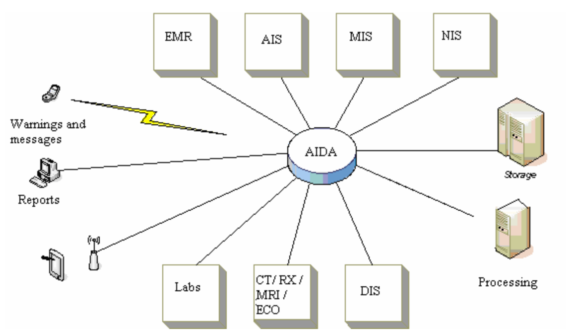

Figure 2 – The AIDA modules

AIDA – Agency for Integration, Diffusion and Archive of Medical Information (Figure1) - is an agency that provides intelligent electronic workers, here defined as agents, that present a pro-active behaviour, and are in charge of tasks such as the communications among the different sub-systems, sending and receiving information (e.g. medical or clinical reports, images, collections of data, prescriptions), managing and saving the information and answering to information requests, in time [2][3]. The main goal is to integrate, diffuse and archive large sets of information from heterogeneous sources (e.g. departments, services, units, computers, medical equipments). Under these presuppositions a virtual Healthcare Information System (HIS) is presented (Figure 2), which will be addressed in terms of a virtual Administrative Information System (AIS), which intends to represent, manage and archive the administrative information that is generated during the episode (an episode is a collection of all the operations assigned to the patient since the beginning of the treatment until the end); the virtual Medical Support

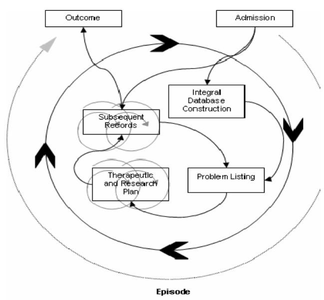

Figure 3: The POMR method

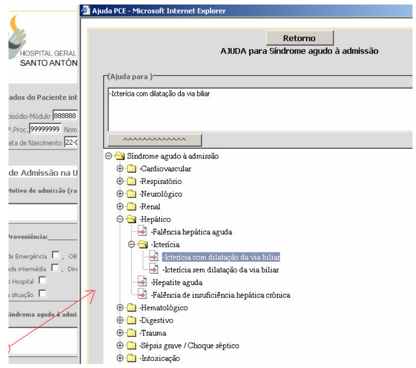

Figure 4 : Procedure Registration with EMR

Information System (MIS), which intends to represent, manage and archive the clinical information during the episode; the virtual Nursing Support Information System (NIS), which intends to represent, manage and archive the nursing information during the episode; the Electronic Medical Record Information System (EMR); and the Distributed 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. Agents exchange messages which are well-formed formulae of the communication language, performing acts or communicative actions [4].

The “intelligence” of the system as a whole arises from the interactions among all the system’s components. The interfaces are based on Web-related front-ends, querying or managing a data warehouse [5]. Such an approach can provide decision support. A context dependent formalism has been used to specify the AIDA system, incorporating facilities such as abstraction, encapsulation and hierarchy, in order to define the system components or agents; the socialization process, at the agent level and the multi-agent one, following other possible way of aggregation and cooperation; the coordination procedure at the agent plane; and the global system behaviour.

3 THE ELECTRONIC MEDICAL RECORD

The Electronic Medical Record (EMR) is a core application which covers horizontally the virtual health care unit and makes possible a transverse analysis of medical records along the several services, units or treated pathologies, bringing to healthcare units new computational models, technologies and tools, based on data warehouses, agents, multi-agent systems and ambient intelligence [6]. Beyond the organizational, functional, technical and scientific requisites, one may have to attend ethical and legal ones, as well as data quality, information security, access control and privacy. An EMR is an assembly of standardized documents, ordered and concise, directed to the register of actions and medical procedures; a set of information compiled by physicians and others health professionals; a register of integral facts, containing all the information regarding patient health data; and a follow up of the risk values and clinical profile. The main goal is to replace hard documents by electronic ones, increasing data processing and reducing time and costs. The patient assistance will be more effective, faster and quality will be improved [7]. The medical training will be based on a rich repository with particular historical cases [8].

Indeed, clinical research and practice involve a process to collect data to systematize knowledge about patients, their health status and the motives of the health care admittance. At the same time, data has to be registered in a structured and organized way, making effective automation and supporting using Information Technologies. For example, from an information repository, one may have collected patient data which is registered in an efficient, consistent, clear and structured way to improve disease knowledge and therapy; the medical processes for registering data are complemented with the information interchange between the different physicians that work around the patient; the clinical data recording are guaranteed in the Electronic Medical Record (EMR) application and procedural context; the protocol to use the EMR is implemented in a secure and efficient way; log files are used to associate physicians to clinical data recording; medical education will be improved.

The process to collect data comes from Problem Oriented Medical Record (POMR) method. This is a format for clinical recording consisting of a problem list; a database including the patient history with physical examination and clinical findings; diagnostic, therapeutic and educational plans; a daily SOAP (Subjective, Objective, Assessment and Plan) progress note. The problem list serves as an index for the reader, each problem being followed through until resolution. This system widely influences note keeping by recognizing the four different phases of the decision making process: data collection; the formulation of problems; the devising of a management plan; and the reviewing of the situation and the revising of the plan if necessary (Figure 3).

Data processing is made taking under consideration organization, structure, systematization and codification. Using concepts and techniques in the domains of knowledge representation and databases, data, objects and structures can be represented. On the other hand, the use of codification systems, scripting and ontologies enable a more natural, automatic, efficient, adaptive and intelligent recording. The system is ubiquitous; i.e. may be used anywhere in the healthcare unit. In Figures 4 it is shown an example of procedure registration using EMR.

4 AMBIENT INTELLIGENCE IN MEDICINE

Ambient intelligence is related with an atmosphere where rational and emotional intelligence is omnipresent. 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 [9][12]. 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 [10].

In virtual health care environments, they may 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 [11] 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.

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.

Ambient Intelligence is related with 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. 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 re-use 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.

5 MODELLING THE SYSTEM

Situation awareness (SA) refers to a person's perception and understanding of their dynamic environment. This awareness and comprehension is critical in making correct decisions that ultimately lead to correct actions in medical care settings. An objective measure of SA may be more sensitive and diagnostic than traditional performance measures. In order to model the system, it is considered an extension to the logic programming language, where a logic program presents two kinds of negation, classical negation "¬" and negation-by-failure "not" [10]. Intuitively, "not a" is true whenever there is no reason to believe "a", whereas "¬a" requires a proof of the negated literal. An extended logic program (program, for short) P is a finite collection of rules r of the form:

$c \leftarrow a_1, \ldots, a_n, \text{not } b_1, \ldots, \text{not } b_m$

where the a_i, b_j, and c are classical ground literals, i.e. either positive atoms or atoms preceded by the classical negation sign ¬ .

One may now obtain, considering the case's predicates gender/2, age/2, isquemic-lesions/2, malign-tumor/2, and hemorrhagy/2 considering Filipa, the logical theory or program:

gender(female, filipa).
$\neg gender(X,Y) \leftarrow$ *not gender(X,Y),not* $exception_{gender}(X,Y)$.
$exception_{malign\text{-}tumor}$*(malign-tumor,filipa).*
$\neg$ *malign-tumor(X,Y)* $\leftarrow$*not malign-tumor(X,Y), not* $exception_{malign\text{-}tumor}(X,Y)$.
age(24, filipa).
$\neg$ *age (X,Y)* $\leftarrow$*not age(X,Y),not* $exception_{age}(X,Y)$.
$exception_{isquemic\text{-}lesions}$*(yes, filipa).*
$exception_{isquemic\text{-}lesions}$*(no, filipa).*
$exception_{isquemic\text{-}lesions}$*(unknown, filipa).*
hemorrhagy(yes, filipa).

It is now possible to define a process of quantification of the quality of information that emerges from the logical program or theory referred to above, in terms of a function L_p, and map its extension, when applied to predicates *gender/2*, *age/2*, *isquemic-lesions/2*, *malign-tumor/2*, *hemorrhage/2* and to *filipa,* into the hyperspace, whose dimension is given by the cardinality of the extensions of the predicates under consideration (Figure 5). The above program is now rewritten in terms of the function L_p (being p a predicate), in the form:

$L_{filipa}(gender) = 1$
$L_{filipa}(malign\text{-}tumor) = 1/N \approx 0 \ (N \gg 0)$
$L_{filipa}(age) = 1$
$L_{filipa}(\ isquemic\text{-}lesions) = 1/3 = 0{,}33$
$L_{filipa}(hemorrhagy)= 1$

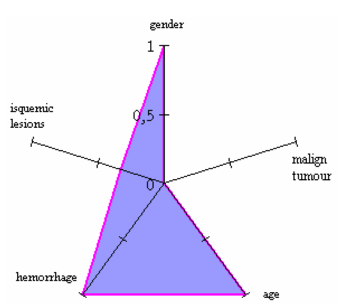

Figure 5 - The quality of information about filipa's state of health

It is therefore possible, through the evaluation of a simple area, to measure or quantify the quality of the information that is carried out by the logic program referred to above, whose values are to be taken in the interval [0,1] [10]. Indeed, logic is broadly concerned with studying inference and expressive power of formal languages with well-defined semantics. As a representation, a plan guides the deliberation and action of a case. Plans are more than programs. It is explored a representation of plans as proofs in a logical theory of action, time and knowledge. This view does not only allow plans to be constructed by logical proof-search techniques, but allows plans to be transformed and reused respecting proof-theoretic principles. It was under this umbrella that AIDA was built [3][4][6][7].

6 CONCLUSIONS

Logic is broadly concerned with studying inference and the expressive power of formal languages with well-defined semantics. To implement the health care virtual scenarios, it was used an extension to the language of Logic Programming that incorporates a measure of the Situation Awareness through the function L_p, which operates on an extended repository containing all the information regarding patient health data and following up clinical profiles. They provide the tools for the physician front-end to any simulation training system. Analysis and interpretation of SA data for both individual and team performance in health care were presented.

ACKNOWLEDGEMENT

We are thankful to the Hospital Geral de Santo António, in Oporto, Portugal, for their help to the analysis and development of the EMR system referred to above, which is now being largely used in their premises.

7 REFERENCES

1. Picard, R. What does it mean for a computer to have emotions?; In Trappl, R.; Petta, P.; and Payr, S. (eds) Emotions in Human and Artefacts, 2003.
2. Weiss, G. (ed), Multi-Agent Systems: A Modern Approach to Distributed Artificial Intelligence, Cambridge, M.A., MIT Press, 1999.
3. Machado J., Abelha A., Santos M. and Neves J., Multi-agent Based Problem Solving in Medical Decision Support Systems, in Proc. of the 2nd International Conference on Knowledge Engineering and Decision Support, Lisbon, 2006.
4. Abelha, A., PhD Thesis, "Multi-agent systems as Working Cooperative Entities in Health Care Units" (In Portuguese), Universidade do Minho, Braga, Portugal, 2004.
5. Abelha A., Machado J., Alves V. e Neves J., Data Warehousing through Multi-Agent Systems in the Medical Arena, in Proceedings of the 1st International Conference on Knowledge Engineering and Decision Support, Porto, Portugal, 2004.
6. Machado J., Abelha A., Neves J. and Santos M., Ambient Intelligence in Medicine, in proc. of the IEEE Biomedical Circuits and Systems Conference, Healthcare Technology, Imperial College, London, UK, 2006.
7. Abelha A., Santos M., Machado J. and Neves J., Auditing Agents in the Context of a Telemedical Information Society, in Knowledge and Decision Technologies, Vale Z., Ramos C. and Faria L. (eds), Lisbon, Portugal (ISBN: 972-8688-39-3), 2006.
8. Machado J. and Alves V., Web-based Simulation in Medicine, in Proceedings of the European Simulation and Modelling Conference, MODELLING AND SIMULATION 2005, Feliz Teixeira JM, Brito AEC (eds), Porto, 2005.
9. Grudin, J., Group Dynamics and Ubiquitous computing, Comm. of the ACM, 45, 12, 2002.
10. Analide, C., Novais, P., Machado, J., and Neves, J. Quality of Knowledge in Virtual Entities, in Encyclopedia of Communities of Practice in Information and Knowledge Management, Idea Group Inc., 436-442, 2006.
11. Kaltenborn K. and Rienhoff O., "Virtual reality in medicine", Meth. Inform. Med., 32(5), 407-417, 1993.
12. Björklind, A., Holmlid, S., "Ambient intelligence to go", White paper on mobile intelligent ambience, 2003.