Leveraging the Learning Process in Health through Clinical Cases Simulator

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Abstract—**This paper presents a multi-agent learning system for health care practitioners named SimDeCS (Simulation for Decision Making in the Health Care Service). The main contribution of this work is the system architecture, model-learning environment supported by artificial intelligence techniques, and its evaluation as a educational software. The SimDeCS was designed as a multi-agent system, composed by three intelligent agents: Domain Agent, Learning Agent and Mediator Agent. The Domain Agent implements the knowledge model by probabilistic reasoning (Bayesian networks), with the knowledge encoded by human experts. The pedagogical strategies emerge from an influence diagram, based on the student's conduct during the simulation. Some results related with the SimDeCs evaluation are presented.**

Keywords—SimDeCS; simulation; Artificial Inteligence

I. INTRODUCTION

It is regarded as a huge preoccupation among educators to fill in the gaps between theoretical learning and the essential clinical practice for medical formation. The number of necessary clinical situations in a real world to support the applied theory in courses in the medical area is quite large and it is not always attainable in a practical way. Nowadays young people have a more interactive way to relate with the world, considering the internet as an indispensable part of their lives [1]. This technological insertion permits us to consider the use of informatics in this educational context. Instead of becoming mere appreciators of the technology, we should associate with it by using it as a tool in the development of citizenship and in pedagogical activity [2].

To make use of simulation methods in clinical practice situations in order to reproduce difficult circumstances in the real world, with the intent to educate, is a commotion that arouses pedagogical interest [3][4][5]. Due to the fact that they are techniques that imitate a real environment by means of analogies, the simulations become complementary to traditional teaching and present the advantage in training educators in the ability of experimenting an emergency state of affairs before they take place in clinical practice [6]. Authors as [7] point out that a computational simulation can improve learning procured in literature. According to [8], asynchronous online education that figures with simulators is an interesting and practicable alternative for students in traditional classes.

According to [9], medical teaching simulators may be understood as tools that permit educators to keep control in pre-selected clinical settings, discarding any potential risk to the patient within this phase of learning. This affirmation highlights the importance of the educator in creating simulations for the students in controlled environments. Once learning with real patients, different from conventional situations, not all variables can be controlled or measured. For this reason, simulations grant total control to the educator with immediate feedback [10], reinforcing his teaching in points that could have passed by unnoticed in case it attains a satisfactory conclusion.

Kincaid et al. [11] present several advantages in the use of simulators for medical teaching such as: 1) aiding the student to comprehend complex relations that otherwise would demand expensive equipment or potentially dangerous experiments; 2) bestow the application of scientific and technological knowledge in an integrated and simulated manner; 3) allow the student to search for new methods and strategies for the solution of a study case; 4) reduce the risk of authentic situations.

Besides the advantages in simulation, the emission of immediate feedback to the student strengthens his learning and makes him ruminate and, as a consequence, forward himself in the right direction when necessary. According to Botezatu [3], the feedback evaluation is a significant learning tool.

The UnA-SUS (Open University of the Health Care System) is a project carried out by the Brazilian Ministry of Health with the Pan-American Health Organization, along with the National School of Public Health, that tends to build up conditions for the operation of a Brazilian network for permanent education in health care, integrating academic institutions that composes it with health services and the SUS management. UnA-SUS was created, by the year 2008, to fulfill the request in the formation of human resources in the Brazilian health care system.

The UnA-SUS is a collaborative network of academic institutions and, among its specific objectives, has as a purpose to virtually offer qualification to those who work in the health domain. The Federal University of Health

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Sciences of Porto Alegre (UFCSPA) in Brazil is one of the teaching institutions that integrate UnA-SUS.

Simulation of real medical's cases in Web environment, as a support for the continuous formation of professionals at service has a strategic importance as it makes possible in upgrading the diagnostic reasoning of the student-workers and makes them reflect.

This paper introduces the simulator SimDeCS (Simulation for Decision Making in the Health Care Service)developed by the Research Group of Distance Education Teaching Health areas of the UFCSPA, which is a multi-agent intelligent learning environment developed as a serious game, with basis on probabilistic reasoning. An evaluation of simulator is presented.

Next section will be devoted to present SimDeCS with special emphasis on general concepts on Bayesian Networks, Multi-agent Systems and Influence Diagram; the steps in the simulation construction of the SimDeCS; its interaction between the student and the simulator; and its evaluation while educational software. Finally, the paper ends with some final remarks and future work perspectives.

II. SIMULATION FOR DECISION MAKING IN THE HEALTH CARE SERVICE

A. *Background*

Three important concepts that are Bayesian Networks, Multi-agent Systems and Influence Diagram in the area of Artificial Intelligence were employed for the construction of the Simulation for Decision Making in the Health Care Service (SimDeCS) as presented in this section.

Due to its utility in modeling and treatment in uncertainty, Bayesian Networks (BN) has gained notable importance in the scientific world, mainly in the medical field [13]. Considering its frequent utilization and principally its intimate link in the diagnostic area, Bayesian Networks appear to be quite adequate in the use of clinical case simulators. In a distinct direction, a discussion has been brought up by Pearl [14] where it is suggested that human reasoning should adopt a different strategy that deviates the focus on the quantitative facet of the representation of probabilities in order to give more attention to dependency relations among variables. This brings it directly to the conclusion that the structure of knowledge used for human evaluation is of the type of dependency graphs and that to go through the connections between its nodes consists on the basic processes of research. Aligned with this impression comes forward the concept of Bayesian Networks. An example of part of a Bayesian Network for a headache used in the SimDeCS project is presented in Fig. 1.

The Multi-agent Systems (MAS) are systems composed of multiple agents that show an autonomous behavior, but interact at the same time with other agents present in the system. The agents exhibit two fundamental characteristics: 1) ability to act in an autonomous way, making decisions that head towards the satisfaction of its objectives; 2) ability to interact with other agents by means of protocols of social interaction inspired in humans and including at least some of the following functionalities: coordination, cooperation, competition and negotiation [12]. A Multi-agent System is a computational system where two or more agents interact, or work together in a manner to carry out certain tasks or satisfy a set of objectives. The SimDeCS is composed of three artificial agents and its interaction is represented in the Fig. 2.

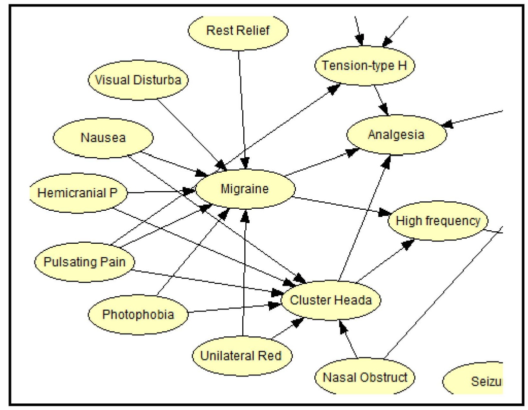

Fig. 1. Bayesian Network for a headache

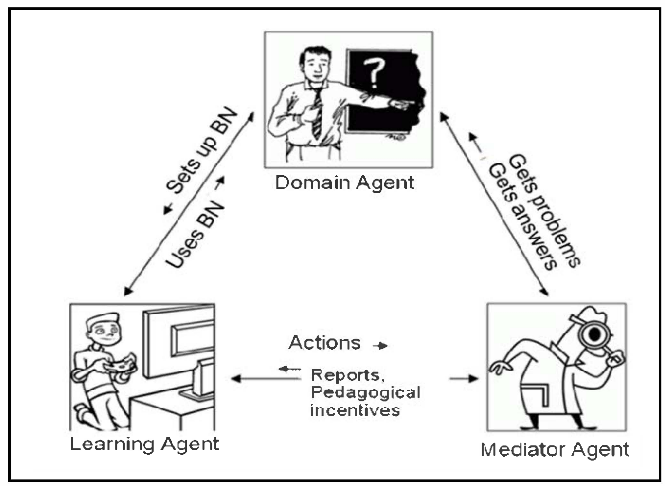

Fig. 2. SimDeCS multi-agent environment

The Domain Agent is responsible for knowledge management. The fact of its being based on Bayesian networks and clinical cases of varying degrees of complexity made it become modeled by expert clinicians and collected in a repository. The Learner Agent represents the learner/user and his actions in the simulation. This agent is implemented by the environment interface and obtains evidence concerning the status of the student's learning process in a way that the student can interact with the simulation. The Learner Agent propagates collected evidence (signs and symptoms of patients) throughout the Bayesian network administered by the Domain Agent that verifies the course of the student's diagnostic reasoning. By means of actions executed by the student as, for example, soliciting an exam, the Domain Agent can infer the student's diagnostic hypothesis as well as the search for evidence in a wrong way. The Mediator Agent manages the interaction between the two other agents and proposes Pedagogical Negotiation (PN) [13], by means of pedagogical strategies when necessary. This agent carries out decisions on how and when to interfere during the student's interaction with the system. It will select the most appropriate pedagogical strategy to query and aid students during their learning processes. The agent supervises and evaluates student performance, guides the learner/user and produces assessment reports. The final generation of performance reports based on the corrections of investigative conducts (and not only diagnostic hits), wasted time and estimated cost, permits the professor to evaluate in these dimensions on the student's performance in the SimDeCS.

An Influence Diagram (ID), according to [14] is visual representation of the decision of a problem that provides an intuitive way and presents essential elements including decisions, uncertainties and objectives, and on how each one influences the other. An Influence Diagram is an acyclic graph directed with three types of nodes: decision (that represents decisions or alternatives), chance (representing occurrences and uncertain results) and consequence (representing the consequence of decisions). An objective combines multiple sub-objectives or attributes that can be in conflict such as energy costs, benefits and risk environments. Generally the objective is uncertain where the analysis of decision suggests maximizing the expected value or, generically, an expected utility based on risk. In the SimDeCS the ID is used in the selection of the best pedagogical strategy to be offered to a student during the execution of a clinical case simulation. In order to select an ideal message to be emitted to the student, the Mediator agent of the SimDeCS analyzes two important aspects of the student's behavior during simulation: confidence and credibility. The ID represents the credibility of the simulator on the student which is calculated based on collected variables during simulation such as creating a record of the patient, the number of questioned bogus nodes, and the investigation process, which takes into consideration the questions carried out during anamnesis, physical examination and complementary exams [15].

B. *The Simulation Construction*

The steps in the simulation construction of the SimDeCS are presented in Fig. 3 where, in the sequence, each number refers to a specific step.

Step 1: the specialist structures the knowledge of the medical domain in a Bayesian Network (BN) by using Clinical Guidelines as a basic source. These guidelines attempt to compile the best available evidence in pertinent clinical problems towards primary attention and are made available through the Brazilian Society of Family Medicine and Community (SBMFC) in the form of texts, tables and flux sheets. Some of the SBMFC guidelines have been adopted to be modeled by Bayesian networks within the SimDeCS project.

Step 2: Clinical cases are developed by a professor and represented in a BN that was previously built by the domain expert. Once symptoms and signs are freely made available on the BN, the professor propagates probabilities by emerging one or more diagnosis with its respective conducts, thus modeling the case that will be simulated by the students. The clinical cases are stored in a database (DB) being composed by the selected nodes by a professor for diagnosis, conduct and investigation stages. Additional information is also stored in the DB regarding the clinical case, as well as the patient's medical records. The network nodes that compose the clinical case are stored in a format of questions available during simulation. Once a question is made, the simulator consults the BN propagated by the professor and attains a reply that expresses the probability of the node at that instant in a colloquial way.

Step 3: The Learner Agent interacts with students by means of a game. This game is the main form of interaction between SimDeCS and its students, presenting clinical cases and allowing students to model and submit their diagnostic hypothesis.

Step 4: The SimDeCS MAS architecture is shown in area 4, whose functionality is described in the previous subsection. The role of the Mediator Agent is to mediate the interactions between the student (Learner Agent) and the tutor (Domain Agent) at each stage of consultation with a patient. This agent uses an ID, to select the strategy that will display the best utility in different moments of the interaction.

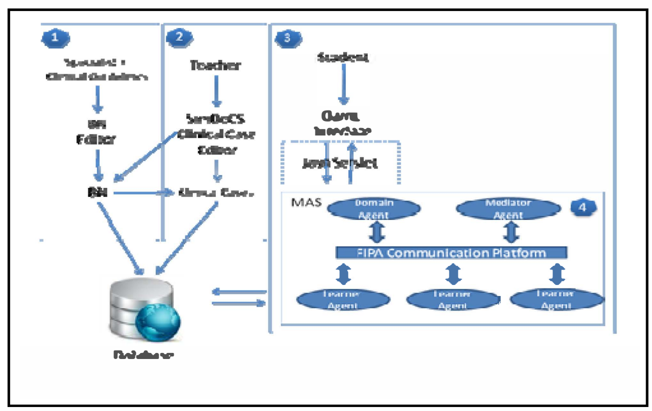

Fig. 3. SimDeCS simulation construction process

C. *Interface of the SimDeCS Simulator*

The medical student can make use of the SimDeCS as a complementary tool in order to facilitate the development of his technical abilities and competence concerning formulated diagnosis by following his own learning rhythm. The medical diagnosis formulation process can be seen composed by certain steps such as: medical interview, physical exam, formulation of diagnostic hypothesis, and a requisition (or not) of complementary exams. Once with the diagnosis at hand, the physician elaborates the conduct that may be the prescription of a certain medication, the solicitation of new exams, or forwarding to a specialist [16]. The interaction between the student and the SimDeCS is done by means of a virtual environment where the "dialog" is built amid the student and the patient. The Fig. 4 presents the SimDeCS simulator interface.

III. EVALUATION OF SIMDECS

The SimDeCS was evaluated in terms of technical quality and usability, complying with Brazilian standard ISO/IEC 14598-6 [17], which recommends a minimum of eight evaluators. This standard evaluates the software's functionality, reliability, usability, efficiency, maintainability and portability, while each characteristic is composed of sub-characteristics that total the items evaluated by the experts. The evaluation instrument was developed based on two previous studies that focused on the evaluation software for healthcare, [18][19].

Fig. 4. Interface of the SimDeCS

Aiming to evaluate the simulator tool SimDeCS as educational software, a workshop was held with the sample of 24 people, composed by 13 doctors, 05 teachers, 05 undergraduate students and 01 graduate student. It should be noted that this sample is in a non-probabilistic sample, i.e. it was composed for the convenience of researchers. During the workshop, all reported having computer knowledge and frequently used software like word processors, spreadsheets, presentation software and Internet. A questionnaire was designed to allow data collection is divided in six blocks of questions seeking to assess: 1) the methodology used SimDeCS, 2) features, 3) reliability, 4) usability, 5) efficiency and 6) learning provided by the simulator. A 5-point Likert scale was used in the questionnaire, and a value of 1 means "Strongly Disagree" and the value 5 means "Strongly Agree". Table I presents a compilation of responses from participants.

TABLE I. PARTICIPANTS' ANSWERS IN THE EVALUATION OF SIMDECS

	Strongly Agree	**Agree**	**Indifferent**	**Disagree**	**Totally disagree**
Methodology applied in the simulator					
The simulator facilitates the thinking of a diagnosis based on evidence.		24			
The simulator provides an easy indication of conduct based on the evidence and diagnostics.		22	2		
The resources available are not sufficient for the study of a clinical case.		21	1	2	
The presentation of feedback allowing the student to return to a question and correct, facilitates learning,		22	2		
At the end of the service the simulator provides students with an opportunity to review the process of resolving the clinical case, allowing a better understanding and learning content.		23	1		
Features of the Simulator					
The initial description and sequential simulator is clear and objective, leading the player to understand what must be done.		22	1	1	
The software has features that enable proper execution of the simulator.		22	2	1	
I realize the consistent and reliable information Simulator.		21	3		
The simulator is accurate in partial and final results.		17	4	3	
The simulator is available by internet.		20	3	1	
In the simulator are not met the ethical and moral health.		20	3	1	
The Simulator provides access security by passwords and different profiles.		19	5		
Reliability in the use of the Simulator					
The simulator has errors frequently.		14	6	4	
The simulator reports clearly when errors occur.		9	11	4	
The simulator informs the user about invalid data input.		14	7	3	
The simulator is able to recover data in case of failure.		6	15	3	
Usability of the Simulator					
The simulator's interface facilitates its use intuitive.		19	3	2	
The functions in the simulator are easy to perform.		21		3	
The simulator is easy to learn and use.		21		3	

	Strongly Agree	Agree	Indifferent	Disagree	Totally disagree
It is easy to operate and control the simulator.		20	1	3	
There is clarity in help content presented during the execution of the simulator.		19	1	4	
Efficiency of the Simulator					
The response time in interactions with the simulator is suitable.		21		3	
The execution time of each case is adequate.		21	1	2	
Learning using the Simulator					
The simulator allows the user to retain knowledge.		20	4		
The Simulator is a motivational tool for learning.		23		1	
The feedback from the simulator is suitable to the student.		19	1	4	
The simulator allows greater student participation, interfering in the pedagogical relationship teacher X student.		21	3		
The simulator does not encourage students to study independently.		22		2	
The simulator can be used as an effective resource in medical education.		22	2		

The Table II presents some comments about the SimDeCS.

TABLE II. COMMENTS FROM PARTICIPANTS ABOUT THE EVALUATION SIMDECS

1	"I really enjoyed taking part in this study. The simulator can greatly assist clinicians in resolving cases that require further analysis, providing data in the literature to think. Important also the literature reviews that are available, facilitating a quick search for information ... "
2	"I think it is very dynamic, and promotes learning. '
3	"It gives tips to really rethink what we set up as data makes us think of the proposed clinical situation ..."
4	"I really enjoyed, makes us imagine a real situation and to facilitate the diagnostic methodology used in everyday life."

IV. FINAL REMARKS AND FUTURE WORK

Simulators have become widely adopted support tools for the education and continuing medical development of health care professionals. Several aspects contribute to this, namely, the simulation model is close to the clinical experience, users can interact with virtual characters (avatars) representing real life characters involved in a clinical history, and the interactive clinical case simulation directly observes and records clinical decision-making in real time. Moreover, interactive clinical case simulation can provide a safe environment for problem based learning as it simulates virtually the diagnosis and treatment phases of the real clinical process.

The SimDeCS simulation tool has been developed to offer monitoring of the user/medical student during the simulation process, providing feedback and guidance on the clinical decisions made, by means of intelligent agents, in order to discharge pedagogical tactics, and recording automatically the clinical reasoning of the user/learner as well as the time spent, thus allowing for assessment of the user/player performance.

Bayesian networks and Influence Diagram are adequate to model knowledge and to support reasoning under uncertainty knowledge modelling, under the purposes of the project. The kernel of the simulation tools is therefore composed by Bayesian networks where knowledge is modelled by professionals in the health care area through clinical guidelines set up by the Brazilian Society of Family Medicine and Community.

The use of a multi-agent architecture in this type of situation makes its implementation possible, mainly in Web developing environments, modularizing development and generating a final product of greater quality and scientific relevance.

Several works have been devoted to this purpose counting with professionals in the health care area to model the specific knowledge in Bayesian networks, which also includes experts in the computational area modelling agents, and specialists in education, all working with pedagogical tactics to forward along with professionals in the area of simulators in the front-end development or friendly user interface.

As to the system itself, it is at its final stage of development with three networks (headache, dyspepsia and parasitosis), making it possible to mold around 80 clinical cases by professors who care to delineate each personal case. Ten clinical cases alone have been prepared for the headache network for the students to exercise.

In the evaluation of SimDeCS observed that the sample that participated in the Workshop believes that it presents quality when it comes to learning. It appears that according to assessments obtained, 84% of sampled believe that the simulator enables the user to retain knowledge, 96% consider the simulator as a motivational tool for learning, 86% consider that the simulator allows for greater student participation, interfering the pedagogical relationship teacher-student, 92% believe that the simulator can be used as an effective remedy in medical education. The average satisfaction with the methodology applied, according to the ratings obtained was 94% and the average satisfaction with the implemented features was 84% and the average satisfaction with the usability was 79% and the average satisfaction with efficiency was 88%, and finally the average satisfaction with reliability was 45%.

The results show the suitability of applying simulators with the characteristics presented in the teaching-learning process in the medical area, becoming real and effective in augmenting the learning process in health. The results described are to be interpreted based on the sample applied was not probabilistic.

As future work we intend to validate the SimDeCS simulator tool within the teaching-learning process, i.e., include in the same subjects and use them as teaching tools, filling in an efficient and productive, the gap between theory and practice in training physicians.

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