An Intelligent Tutoring System for SIMFOR: A Serious Game for Crises Management

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Abstract—In this paper we propose to bring together the concept of Serious Game and Intelligent Tutoring Systems (ITS) in the context of the SIMFOR project, a serious game for training in crisis management. We discuss the problems and needs of serious games and a overview of existing work. To enhance the learning aspect in serious games, we propose the integration of different ITS modules to the serious game. This integration is realized in the design of a collaborative multi-agent system that represents the different module of an ITS.

I. Introduction

All cities are confronted to major risk management. Today, in response to major risks, business leaders, schools, cities or regions should implement specific prevention plans and improve stakeholders awareness with scenarios exercises. Indeed, the only way to test these plans is to make exercises in real conditions, which can become very heavy in terms of organization and very expensive. To reduce the cost and saving time, computer tools are solicited. There are many tools dealing with the issue of risk management. In [1], Amokrane discusses the problem of risk management in SEVESO sites (high-risk site) for staff training. In [2], Querrec proposes SecuReVi, a training tool for firefighters. In Marion and colleagues work [3], risk management is discussed in safety on aircraft carriers. However the large majority of these tools do not satisfy the demand of risk management actors and are reserved for specialized trades target (eg firefighters) or to a particular domain. The objective we have with SIMFOR is to propose a serious game dedicated to train non-professional to risk management, and this through enhancing the educational aspect by adding different modules of an Intelligent Tutoring System (ITS). This integration is achieved by designing a collaborative multi-agent system to ensure the monitoring process and evaluation of learners.

In this paper we present the concept of serious game, we discuss the problems and needs of serious games, especially in pedagogy, by making the analogy with Intelligent Tutoring Systems. In section II, we present SIMFOR, a serious game for training of non-professionals in risk management. In section III, we present the functional modules of an ITS. In section III-B, we compare different work in the field of serious games and ITS. In section IV we present our initial work for the project SIMFOR. And finally in section V we conclude and present future works for SIMFOR project.

II. Serious games : SIMFOR project

Some people consider the term *"serious game"* as an oxymoron expression, because the two words are contradictory, domain professionals define a serious game as a game that focuses on education rather than entertainment [4]. There are other definitions in the computer field such as Michael Zyda definition [5] who defines a serious game by a cerebral challenge, played with a computer which uses the entertainment as an added value. There are also approaches from the field of psychology such as André Tricot definition [6] that focuses on the pedagogical scenario. In [7], Julian Alvarez

offers a unified definition of a serious game: *A computer application, [aims] to combine with consistency, both serious (Serious) aspects such as non-exhaustive and non-exclusive, teaching, learning, communication, or the information, with playful springs from the video game (Game)"*, adding this association must be done by implementing a pedagogical scenario. In the next section we will discuss serious games needs and issues, especially in pedagogy.

The most important point in a serious game is the pedagogical support provided to the learner. In this context, the concept of adaptive serious games is often used. Adaptation, as applied to a Serious Game, reflects its ability to change structurally in response to certain events triggered by the learner (player). In [8] Hocine presents a general state of the art on different adaptive serious games. These different works do not take into account the area studied and have a simple representation of the learner. Intelligent Tutoring System (ITS) constitutes another approach stemmed from the Technology Enhancing Learning (TEL) researcher community aiming at individualizing training. ITSs propose to represent (explicitly or not) knowledge (declarative or procedural) from the domain under study [9] as well as knowledge to be acquired by the learner (its mental state)[10] during training session. We'll go into more details on ITS in section III.

A. Presentation of SIMFOR project

SIMFOR is a serious game developed by SII[1] in partnership with Pixxim[2], in response to serious gaming call for project launched by the french Secretary of State for Forward Planning and Development of the digital economy. SIMFOR (Figure 1) provides a fun and original approach for learning risk management as a Serious Game. SIMFOR is adapted to actors' (of a training session) needs and enables learners to train for major risk management by integrating multi-stakeholder aspect. The project objective is to create a tool that provides users a context of risk management in real-time and realis-

tic in terms of environment, self-evolving scenarios and actors.

Fig. 1.   Screenshot from SIMFOR project

B. SIMFOR challenging issues

The SIMFOR project faces two issues:

- the *simulation of human behaviour* of non playing actors in a scenario.
- The *monitoring and evaluation* of learners during their training.

SIMFOR is a multi-player game and allows different people to learn skill (shared or specific) in the same game. This is possible because SIMFOR does not target the specialists in the field of risk management, but rather the non-professional. Managing a major crisis can mobilize several hundred stakeholders, from the regional Prefect in his office to the firefighter in the field. These stakeholders are required to communicate and work together in order to restore a normal situation.

Many works, in the literature, relates the learner support and assessment issues [11][12], but SIMFOR is a multi-actor game dealing with two types of evaluation: individual and collective. Solving the crisis requires the resolution of all procedures of the stakeholders, so individual evaluation can affect the collective evaluation, and the collective evaluation can affect the individual evaluation too. For

example if a learner has successfully realized his procedures, but the main purpose was not reached (material and human loss for example), the learners must be evaluated on their individual and collective performance to infer the reason of failure (lack of communication, missing procedure of another learner, ...).

III. INTELLIGENT TURORING SYSTEMS

The intelligent tutoring systems covers three disciplines: computer science, psychology and education. In this section we present the modules of an intelligent tutoring system (III-A), and a comparison of different works done in the field of ITS and serious games (III-B).

A. Architecture of an ITS

Burns [13] defines an ITS architecture with: i) an *Expert module* containing the expert domain knowledge; ii) a *Learner module* that contains what learner knows in the domain; iii) a *Tutor module* which aims at identifying the learning gaps so the system can adapts its strategies to help the learner in filling these gaps (module also called Pedagogical module) and iv) two modules representing the communication channel of the ITS : the *Learning environment* and the *Human-Computer Interface*. Their roles are detailed below.

- **Expert module**: J. Anderson [9] identifies the most important task in the design of the expert module as how to model (codify) knowledge. The expert module must contain specific and detailed knowledge from people with many years of experience in a particular domain.
- **Learner module**: an ITS must construct a model for understanding the learner and then use this understanding to adapt instructions to the specific needs of the learner. The learner module typically use the same type of knowledge representation used in the expert module ie represented as a subset of expert knowledge.
- **Tutor module**: An ITS must have three tutoring characteristics: a) the control over the representation of educational knowledge for the selecting and scheduling the exercises; b) the ability to answer questions from students

on educational objectives and content, and finally c) strategies to determine when "students" need help with their solutions.

- **Pedagogical environment**: The pedagogical environment is an important component in an ITS. It supports the learner during his training (implying monitoring), it includes the tools provided by the system to facilitate the learning.
- **Human-Computer interface - HCI**: The problem in the design of human-computer interface is that the student must use the technology itself to learn, while being not necessarily an expert user. If the HCI is badly designed, a training session will probably be ineffective. In other words, if the learner has to spend significant intellectual energy to interact with the computer, the learner will be less intellectual and emotional energy to learn the skills.

B. ITS and serious game : Comparitive study

Table 1 compares different works in the domain of serious gaming and intelligent tutoring systems. These works cover different and varied scopes. We took five comparison criteria that we consider important for our research:

- *Environment*, a 3D environment generally reinforces the learner immersion, but it also depends on the (domain) application.
- *Multi-learners ability* which describes the difficulty of modelling a collaborative process between different learners (managing communications and interactions).
- *Evaluation* is useful to measure the performance of the learner. It is more difficult if the serious games (ITS) is multi-learner (it adds a notion of collective assessment (section II-B).
- *Replay*. The latter aims to reproduce a learner's sequence of actions/decisions during a game session to allow the learner and the trainer to re-visualize the activity carried out for the debriefing.

In [12], Lourdeaux offers a tool-based ITS to train High Speed rail (TGV) driver. Lourdeaux proposes the concept of HAL (Help Agent for Learning). The training environment of HAL is based

Project	scope	environment	multi-learner	evaluation	replay
[14]	risk management (aircraft-carrier)	**3D**	**yes**	no	no
[12]	railway (TGV driver)	**3D+VR**	no	no	no
[15]	risk management (SEVESO site)	**3D**	no	**yes**	**yes**
[16]	road safety (police)	**3D**	no	**yes**	**yes**
[17]	medical (nurse)	**3D**	no (planned)	no	no
[18]	business management	2D	no	no	no

on virtual reality with a reproduction of a TGV cockpit and a giant screen to display the 3D environment. However, HAL is single-learner and has not an evaluation module or system replay. In the domain of risk management, the PEGASE system (Pedagogical Generic and Adaptive System) is a training tool for risk management on aircraft carrier, but limited to crew members and has no evaluation and replay capability. Still in risk management, Amokrane [1] proposes a training system for Seveso sites management (ie with high industrial risk) called HERA (Helpful agent for safEty leaRning in Virtual Environment). HERA deals with the evaluation of learners and has a replay module, but HERA is a single-learner system and does not address the problem of collective evaluation. In the domain of serious games, Binsubaih's serious game [16] target police force traffic accidents management training. This game has a very sophisticated mechanism for evaluation, however, it remains poor in teaching and supporting learners. In the health domain, Vidani [17] designs a serious game for training nurses, this game has a players' support module but remains quite limited as learner's freedom is limited and offers actions to be performed. We can also find serious games with a 2D environment, where the 2D suffices to represent the learning environment as in [18], a serious game where you learn to manage a company by using various tools (email, printer, fax, ...).

Our goal with SIMFOR is to keep the serious games aspect of SIMFOR (game mechanisms, 3D environment, ...) and adding different ITS modules: the learner module, domain module and the pedagogical module. The interface module will be represented by the SIMFOR interface maintaining a playful learning principle while improving the adaptive aspect with the ITS modules.

IV. OUR WORK IN SIMFOR PROJECT

Our research work covers two aspects of the SIMFOR needs: upgrading SIMFOR into an ITS while maintaining the didactical aspect of a serious game:

- Design and development of a multiagent model to simulate the behaviour of the scenario's actors.
- Design a collective evaluation method based on agents.

The second objective led us to design a cooperative multi-agent system that contains the different module of an ITS including a serious game (SIMFOR). Figure 2 describe the different module of the system. In the next section we will see in more details the architecture of the proposed model.

A. Architecture

The system is composed of the following components:

1) A Serious Game: SIMFOR has 3D models, an user interface, a simulation module, and data models (Actor, Means and Disaster). By analogy with intelligent tutoring system, the user interface and the pedagogical environment are represented by SIMFOR 3D Ui (figure 1). The 3D environment plays a very important role because the 3D brings immersive aspect to the player, allowing players to immerse themselves in their role and to ignore the tool used (computer, simulator, ...).
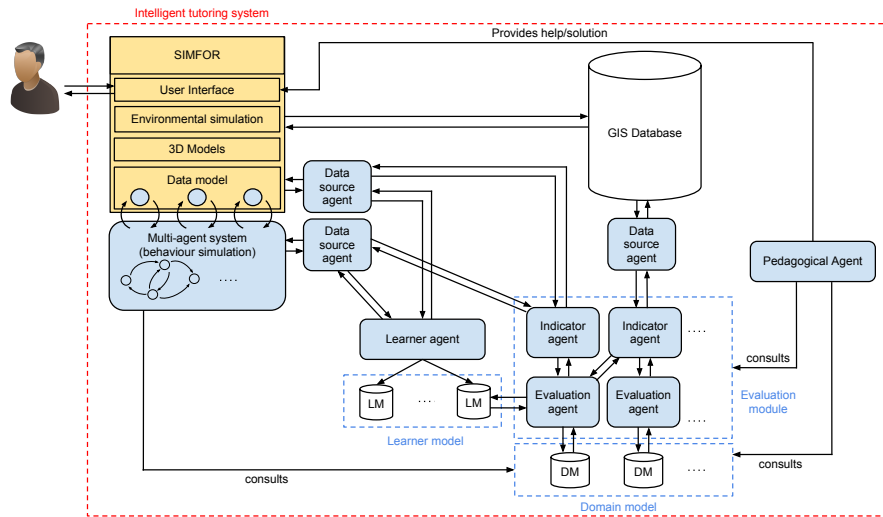
Fig. 2. General working of the system

2) Behaviours simulation: To simulate human behaviour, we have added an AI (Artificial Intelligence) module that simulates humans behaviours which enables to manage actors who are not played. For this we have implemented an architecture model based on a *ad hoc* BDI (Belief Desire Intention) agent [19] (game agent). We have facilitated the design of agent by providing the designer (of the scenario) an editor to configure and set up agents. The multi-agent system can handle game models to simulate human behaviour (displacement of an actor, intervention on disaster, ...).

3) Evaluation modules: The evaluation module aims to provide an assessment in real time to the pedagogical agent. This module is composed of the following agents:

- **Data source agent**, for each "information" component, a data source agent is associated, the data source agent have for mission to collect the necessary information for the monitoring process.
- **The indicator agent**, this kind of agent have to compute or to select the appropriate indicator for learner evaluation.
- **Evaluation Agent**, using indicators, the Evaluation Agent assess learners performance. The

result of evaluation is used thereafter by the pedagogical agent and can also be used for post-game debriefing.

4) Pedagogical agent: The pedagogical agent plays the role of a virtual tutor accompanying the learner in his training. The pedagogical agent provide support and help to the learner to optimize learning in the virtual environment. The pedagogical agent represents the tutor module of ITS, it analyses the situation (evaluation module, domain module, learner module) and select the appropriate strategy (propose action to perform, display help, correct, ...).

5) Knowledge representation: Knowledge used or produced are stored in the following models

- **The domain model**, the domain model represent the different concepts of crisis management and its segmented into parts representing a role or a skill to learn. The domain model is represented by an ontology that describe the different concepts of risk management. Presently, the ontology is specific to SIMFOR but will be extended to respond to every request of a domain expert. The domain model represents the expert module of an ITS.
- **The learner model**, for each learner or agent,

a learner model is associated. This model represents the mental state of actors at the time t. The Learner Agent (LAg) collects learner actions and knowledge, and stores them in the learner model. The LAg also collects agent knowledge and actions, this information will be used for collective evaluation. The learner model and the LAg represent the learner module of an ITS. The data structure of learner model is the same structure of the domain model, and it is an ontology, in order to use the knowledge overlap by the evaluation agent.

B. General working of the system

Figure 3 describes, with an UML sequence diagram, the interaction between different agents of the training system during the monitoring process. At each time cycle, the pedagogical agent analyses the game situation to help learner. Thus the Pedagogical Agent sends request to Evaluation agents to get learner assessment (arrow 2, figure 3). The evaluation agent request learner model to get learner information (3) (level, role, pending procedure, ...), then the Evaluation agent requests an Indicator agent the adequate indicators for the evaluation (4). The indicator agent ask the adequate data source agent to calculate indicator (5) (data from simulation, from data base, ...). The data source agent can receive raw data continuously (0), and when its receive request from an indicator agent, the data source agent serialize raw data (or consolidate it) and sends it to the indicator agent (6) which in turn calculates (selects) adequate indicator and send it to evaluation agent (7). With learner information and domain model, the evaluation agent computes an evaluation and sends the result to pedagogical agent (9). The pedagogical agent can then use domain model information (10) to predict the next course of action and selects a strategy to provide a support to learner through the SIMFOR 3D interface (11).

C. Scenario example

To illustrate how such ITS would work, we present an example of scenario defined with the help of a domain expert. We present a simplified example of the missions to be performed by the actor playing the role of CODIS (Departmental Operational Fire and Rescue Services Centre) for a TDM scenario (Transportation of Dangerous Material). The scenario described a TDM truck which has spilled due to a traffic accident. The tank is damaged and the fuel is spreading over the road. A witness to the accident gave the alarm by calling the CODIS. The CODIS must perform four missions after receiving the alert: CODIS has to send firefighters on the scene to retrieve information about the accident. Once the information on the accident is received (transmitted by the firefighter in the field) and after confirmation of a TDM accident, the CODIS must primarily inform an officer (firefighter) to take the necessary measures. Next, the CODIS must complete an information sheet on the disaster transmitted by fax to the mayor, prefect and the sub-prefect. Finally the last mission is to brief the acting officer in the local OCP (operational command post) once it is sent by the prefect.

The first action to be performed by the CODIS is to call a firefighter to warn them of the accident. When pedagogical agent solicits an assessment (arrow 2, figure 3), the evaluation agent requests the indicator agent (4) which in turn solicits the data source agent (5). For the action call, the indicator agent must select a time of execution to perform the action and the information exchange during the call (if the called is an agent, retrieve the information from the dialogue). The time of execution and information exchange is retrieved from data source agent associated to SIMFOR (if the actor called is an agent, information exchange is retrieved from data source agent associated to the multi-agent system that simulate human behaviours). Depending on the game difficulty and the skill level of the learner, the evaluation agent will compute an assessment that will allow the pedagogical agent to select a strategy (11). Different type of strategy have been defined according to the evaluation result:

- *Let the learner performs the action*: the study conducted by [20] have shown that learners who received delayed feedback have better retention of skills over time. If the student is experimented, the pedagogical agent let the learner find solution by himself.
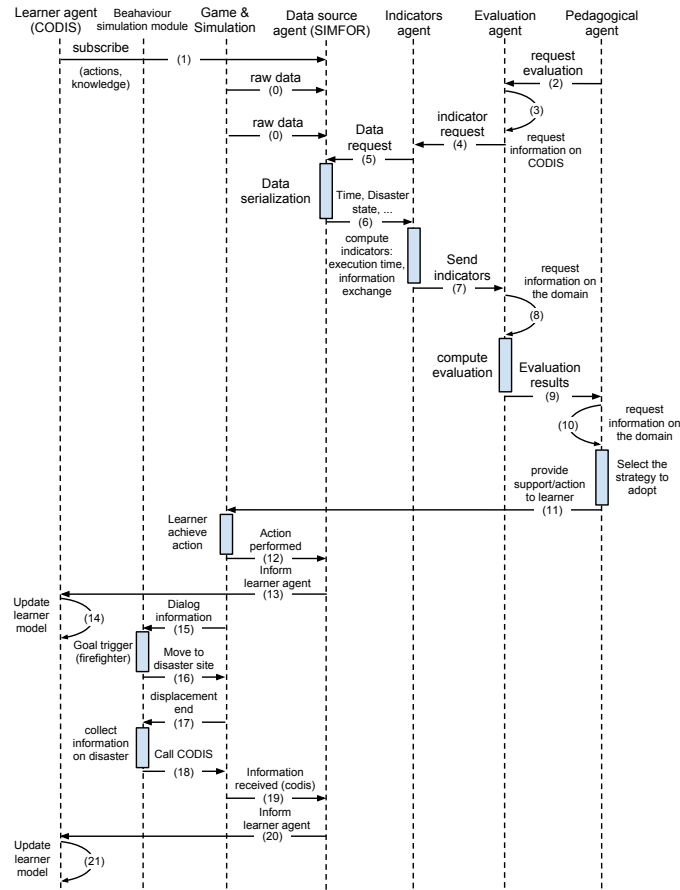
Fig. 3. Sequence diagram of the interaction of different agent

- *Give a clue*: if the learner is a novice, the pedagogical agent begins by giving clues about the procedure to follow.
- Propose action: if the learner has difficulties to perform the procedure (time attributed to the action exceeded), the pedagogical agent propose action to realize (in the case of CODIS, call firefighter).
- *Do the action in place of the learner*: if the learner does not know how to do the action, the pedagogical agent performs the action in place of the learner while also explaining how to do it.

To keep a history of learner actions and his knowledge evolution, the learner agent subscribes to data source agent. So, when learner perform action or revive information, the data source agent inform learner agent (13, 20) and the learner agent update its learner model (14, 21).

When a role is played by an agent (Game Agent), the behaviour simulation module can handle game model (16) and interact with the learner (18).

The evaluation request of the pedagogical agent (2-9) is repeated each time cycle, this is not shown in the diagram for better understanding.

At present the number of action that can be achieved in SIMFOR is somewhat limited, but nevertheless allows to analyse the activity of the learner by comparing the actions performed with

the domain model.

V. Conclusion and perspectives

In this paper we have presented the concept of serious games and their contribution in the field of training. We have highlighted the analogy with intelligent tutoring systems and what could bring the ITS for the serious games in particular as regards the support and monitoring of the learner. We also present our case study SIMFOR, a serious game for training non-professional for risk management. Early work in the project SIMFOR is the integration of different modules of an ITS to enhance the training aspect of the serious game.

Future work in the SIMFOR project target i) the finalization the multi-agent system architecture which simulates non-played actor with organizational architectures such A& A [21]; ii) the addition of a (ITS like) pedagogical module for monitoring players in real time and to offer them pedagogical solutions to help them in their training, and a post-game diagnostic that will identify weaknesses of the learners and the skills and competencies that remain to be acquired. This ITS must also enable monitoring agents (game agent), so the individual and collective evaluation is therefore based on both the human player and the agents (with normal behaviour or intentionally erroneous).

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