SecuReVi : Virtual environments for fire fighting training.

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Abstract: This article describes how to use MASCARET model, a multiagent system for virtual environment for training (VET), to help for firemen training. This VET, called SecuReVi is designed for officers. They have to manage and order teams to solve incidents that they can't have in real situation for training exercises. In this environment the learner has to take into account and manipulate his physical environment (physical phenomena) and his social environment (firemen teams) which can be implemented with the MASCARET model. This article shows also the roles of each actor (designer, teacher and learner) and a typical pedagogical scenario.

Keywords: Virtual Environment for Training, MultiAgents Systems, Fire fighting.

1 Introduction.

To train fire-fighters officer to manage and order teams, classical exercises are founded upon Role Playing Games (RPG) techniques. Theses methods are quite limited in term of interaction and immersion and can cause misunderstood with some learners. As it is impossible to train to real incidents in a real environment, we propose to use virtual environment for fire-fighting training so that the learners can *"learn while doing"*.

Firemen already use computer techniques for teaching and crises simulations. These tools are various types and we classify them according to selected approach. The first type gathers tools founded upon traditional approach of simulation. They use databases and digital models to simulate the evolution of a phenomenon. It is the case, for example in [Gal97]. The second approach is an "agent" approach founded on the interactions between entities which, according to the applications, are users, decision-making aids software or agents in the meaning of multiagent systems [Dur99]. Finally, the last type represents tools adopting a "virtual reality" approach and proposes immersion, navigation and interaction capacities with the simulated environment. Most famous of them is *Vector Command*[1]. All those studies presents however gaps in term of representation and simulation of environment as for learners and teachers immersion. We thus propose a new application called *SecuReVi*.

SecuReVi (safety and virtual reality) is an application of *MASCARET* [Que02] for civil safety. It contributes to firemen officer training in operational management and command. In this article we thus start briefly by describing the *MASCARET* model as well as the virtual reality platform which allows *SecuReVi* implementation. Using this model, conception of *SecuReVi* cuts out in four phases: the modelling of sites, the physical phenomena definition, the agent's behaviour and team's creation.

2 The MASCARET model.

Our problem is to train teams to collaborative and procedural work in a physical environment. In this case, we have to simulate in a *realistic* way this physical environment and the *collaborative* and *adaptive* team member's behaviour in the social environment. Evolution of those environments results from simulation of autonomous agent's local behaviour and their interactions. We use a model called *MASCARET* where multiagent systems permits to simulate realistic, collaborative and adaptive environments for training. This model aims to organize the interactions between agents and to provide them abilities to evolve in this context.

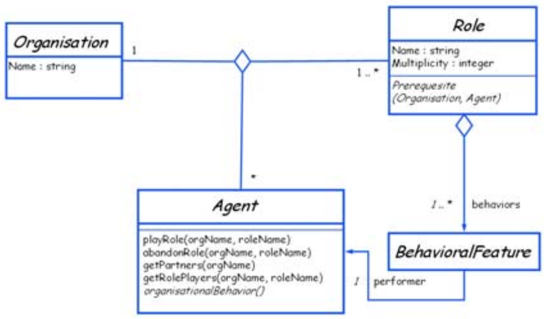

Figure 1: Organisational model.

MASCARET proposes first a generic organisational model allowing representing the physical and the social environment. This model is founded upon the

[1] http://www.vectorcommand.com

concepts of `organisation`, `roles`, `behavioral features` and `agents` (Figure 1). The aim of the `organisation` is to structure interactions between agents, the concept of `role` represents the responsibilities (`behavioral features`) played by `agents` in the organisation. Agents have then an organisational behaviour which permits them to play or abandon a role in an organisation.

This generic organisational model is used to represent the user's physical model. The organisation is, in this case, a network where agents are connected together when they are in interaction situation. To represent the concept of privileged direction in interactions, *MASCARET* defines two particular roles called `source` and `target`. For "real-time" computation reasons, the interactions are detected by one agent playing a `recruiting` role. The agent's elementary behaviour consist in the computation of a vector of internal state variables after the evaluation of inputs (from the interactions where the agent is a target) and presents a pertinent internal state to other agents (potentially targets of an interaction where the former agent is a source).

In *MASCARET* (as for *SecuReVi*), the social environment is structured and each member knows its roles and those of its partners. The interactions between the team members are also structured and arranged by the mean of procedure known by all members. The generic organisational model is derived to formalize this concept of team. We are interested in the case where the action's coordination between team members are already envisaged and written in procedure. On the other hand, the environment being dynamic, agents can need to adapt the scenario to the environment. Procedures have then a semantic representation so that agents can reason above. Procedures describes interactions between agents in an optimal case, and leaves to the agent the responsibility to build implicit plans (not clarified in the procedure) considered as natural within an applicative situation. For that, agents must be able to reason on actions and *MASCARET* proposes a model of goal directed actions having pre-conditions and post-conditions. Thus, before carrying out an action, the agent must make sure that pre-conditions of this one are checked. If it is not the case, it builds itself a plan by back chaining on pre-conditions and post-conditions of actions. When an agent starts or stops actions, it broadcasts a message that enables other members to follow the evolution of the procedure.

3 Implementation

To implement SecuReVi, we used A*ReVi/oRis* platform. *oRis* [Har02] is an environment for interactive simulation: it is a programming language founded upon active objects and an execution environment. Those characteristics make *oRis* a generic platform for multiagent systems implementation, more particularly dedicated to simulation. It is a dynamically interpreted language, with instance granularity witch make possible to intervene in the course of simulation to observe the multiagent system, to interact with agents or on the environment and to modify them on line. In *oRis*, a multiagent system is composed of agents (active objects) whose environment consists of objects, possibly located in space (2D or 3D) and time. *oRis* offers a homogeneous solution for interactions implemented by method calls, reflex or messages (peer to peer or broadcast, with immediate or differed processing by its recipient).

ARéVi [Rei98] is a virtual reality framework whose core is *oRis* and thus all the potentialities of this language are available when designing applications under *AReVi*. It is extended by C++ code offering suitable functionalities for virtual reality and it is founded on *OpenGL Optimizer*. Graphic objects are loaded from *VRML2* files for witch it is possible to define animations and manage level of details. Graphics elements such as transparent or animated textures, lights and *lens flares* are available. *ARéVi* introduce also kinematics functions. As regards the sound field, *ARéVi* proposes three-dimensional sound and synthesis and voice recognition functionalities. This framework manage various peripherals such as data glove, joystick, wheels, localization sensors and head mounted displays which extend the possibilities of user's immersion in the multiagent system.

4 Site modeling

From *MASCARET* model and *AReVi/oRis* framework, the first stage of the realization of *SecuReVi* is the modelling of sites. This task being tiresome, we take care of re-usability of elements already carried out, which result is the use of a standard representation format and creation of a classification and a library.

4.1 Classification

All elements are located *i.e.* they have a position and an orientation. We chose to organize these elements, first to facilitate future development of tools for the sites designing and secondly to simplify the agent's behaviour. The criterion chosen to structure the elements is related to the capacities of movement. From the located entities of MASCARET, we thus defined three classes of entities:

- The mobile entities (`GeoMobile`) have capacities to move in an autonomous way. They are characterized by criteria of mass, including box and kinematics attributes (speed, acceleration...). They are for example vehicles, humanoids and particles.

- The movable entities (`GeoMovable`) have the same characteristics as the preceding entities, but they don't have the capacities to move alone. They undergo the forces of elements (mobile entities) to which they are dependent. They are the firemen tools, some urban furniture and tanks.
- The static elements (`GeoStatic`) can move neither by themselves nor by the forces exerted by other entities. They have an infinite mass, but have an including box for the calculation of obstacles avoidance. They represent, for example, the buildings and large tanks.

Located entities take part, by default, in two interactions networks: a mobility network and a collide network. Mobile entities can then play any role in collision and mobility interactions. On the other hand, movable entities can play only a target role in mobility interactions whereas they can play any role in collision interactions. Lastly, static elements can play only a target role in collision interactions; they don't play any role in mobility interactions.

4.2 Modelling and rendering

Methods used here depend on constraints fixed by virtual environments for training such as credibility and the need of real time computation.

Users must recognize the environment, so it is impossible to use automatic methods for urban landscape generation such as *VUEMS* [Don97]. The method we use is founded upon the construction of geometrical models from plans provided by industrials and civil safety services. This reconstitution is manual and we use modellers such as *3DSMax*. Each element is textured by photographs taken on the site and is recorded in a *VRML* file. Textures taken must be of a good quality because the users "*walk*" inside the scene at ground level what require to spend much time in the treatment of textures. This method requires many memory resources; however, within *SecuReVi*, the rebuilt environments are not very wide: in no case we want to reproduce a whole city, but only sites, or to the maximum a district. The quantity of data thus remains reasonable compared with the current available material resources and does not penalize real time calculation of the simulation. Figure 2 shows the reconstitution of a factory site. This scene represents approximately 50 located entities for a total of 50 000 triangles.

Figure 2: Industrial site 3D reconstitution.

5 The physical environment

The second phase is the physical phenomena simulation. The physical environment consists of the site in which exercises take place as well as the physical phenomena (fire, smoke, jet of water...) which can there intervene. For *SecuReVi*, those phenomena must be as realistic as possible or exaggerated so that the learner feel immerged in the environment. *SecuReVi* is initially intended with outside environment such as industrial sites. Agents of the environment are then flames, gas particles, water jets… The goal of this paragraph is to show the realisation method of the interactions networks in *SecuReVi* by derivation of those defined in *MASCARET* as well as the agents taking part in these networks.

In *SecuReVi*, several types of interactions networks have to be developed, but much of them are to be defined according to the implementation of new scenarios. On the other hand, once implemented, they feed a library and can be used again in other exercises. In the exercise of a gas leakage in a factory site, represented figure 3, the major phenomenon to take into account is the propagation of the gas cloud (displacement and collision) as well as the toxic effect which it can have on live beings.

Figure 3: Example of a physical phenomenon in SecuReVi.

In this example, three interaction's networks exist. The first is the mobility network; it is composed of the wind which is a source and a recruiter as well as the gas particles, which are only targets. The second network is the toxicity network in which humans take part by playing the roles of recruiter and target. The gas particles also take part in it by playing the target role. Finally the third network is the collisions one in which the water walls and the "*tail of peacock*[2]" takes part as a source and a recruiter. The gas particles also take part in it by playing the source role. All these phenomena are interaction networks. Figure 4 shows the way in which the `CollideNet` network derives from `InteractionNet` of *MASCARET*. `CollideNet` has then the roles `Source`, `Target` and `Recruiting`, but defines also a `Collider` role. This role describes in its turn, a reactive behaviour `CollideBehavior`. This mechanism is used for all the interaction networks from the physical environment.

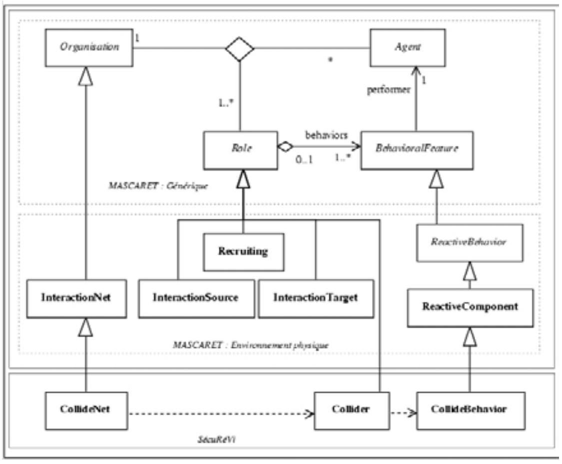

Figure 4: A collide interaction network.

In a teaching scenario we create each of these networks, but the roles assignment to the agents is done in a dynamic way. In the case of gas leakage exercise, only some agents are created at the beginning of the scenario. Thus, the wind start playing the role `Source Recruiting` and `Mobile` at the beginning of the simulation in the `Mobility` network and the gas tanks play the roles of `Target` and `Recruiting` in `ThermicTransfert`. It is during the implementation of agents that the developer indicates the roles that each agent can play, because the assignment of the roles is fixed here. The water jets and the gas particles are created during simulation, and it is at this time that they start to take part in the interaction networks.

Various techniques exist to represent the visual aspect of physical phenomena, but they are related to the model of phenomenon calculation which is often a global model. That makes them unusable in our case because these techniques do not allow user's interactions. Moreover, for a certain number, they are not (or with difficulty) calculable in real time, which create a problem because we want to simulate several types of phenomenon in same simulation. We cannot thus use these techniques in *SecuReVi*. We use systems with particles [Sta00] to represent the jets of water as well as the explosions, and billboards with transparent and animated textures [Har01] to represent the gas particles and fires.

6 The autonomous actors

In *SecuReVi*, agents taking part in the social environment are humanoids. Characters are safety agents from the industrial sites and firemen. They are instances of agent's classes inheriting from `humanoid` class. This class describes traditional competences of human such as walking to a point or to communicate. Designing new classes of agent from this one is justified by addition of new technical skills such as swimming for a plunger, and not by addition of responsibilities to an agent (represented by roles of organizations).


Figure 5: Character's 3D reconstitution.

Various techniques exist for humanoids reconstitution as for their actions. G Thomas [Tho99] proposes some and uses the *H-Anim* standard. We use the *Poser* software (in conformity with the *H-Anim* standard) to create characters and movements. A movement is described by key positions of each part of human; intermediate positions are calculated by interpolation. Then a movement is composed of several poses and the animation of character is obtained then by displaying poses from first one to the last. The various poses can be also obtained from movement captures as with the *Vicon* system. This technique actually starts to be used for virtual reality, but we do not have this expensive technology for *SecuReVi*. Another solution can be to calculate the biomechanical models [Bea01] resulting from these movement captures, unfortunately these models are not yet usable for virtual reality.

[2] It is a firemen tool used to create a water wall. Its name comes from its shape (a tail of peacock).

Technically, in *SecuReVi*, each pose is defined in a VRML file. The platform that we use does not make it possible to reach VRML nodes, it is thus necessary to store in memory each pose. We count on the evolutions of the platform to solve this problem what will enable us to load only one time the file and then reach the nodes to give them their new values according to precalculated animation. Figure 5 shows two poses for one of the characters thus recreated.

These characters inherit from MASCARET agents. So they are autonomous agents, able to realize procedures in collaboration with other members of their organization. These characters are also able to adapt such procedures to the dynamic environment and to calculate, autonomously, implicit plans to reach goals that experts didn't explicit. For example, the first action of procedure n°16 of a FPT team (see next section for FPT explanation) is to get ready. In order to get ready, each agent needs to have its tools. So, agents compute (according to algorithm presented before) an implicit plan allowing them to have their tools. If for some reason (a mistake in the pedagogical scenario for example) an agent can't find all his tools, it will detect the plan have failed and will ask other orders to his head-master.

7 The social environment.

Teams are groups such as the FPT[3], VSAB[4]... whose members are played by autonomous agents. *SecuReVi* is addressed to the head of group (GOC 4) which orders 2 to 4 groups. The goal of *SecuReVi* is to train to decision-making in operational situation, actions of agents must thus have a sufficiently realistic representation to support immersion of user, but not inevitably very precise.

Figure 6: Extract from an intervention plans.

In the case of a gas leakage on a factory site, the objective is to secure the populations, to reduce the propagation of the incident and to protect the tanks in case of ignition of the gas cloud. For that the intervention plan (PPI) envisages the engagement of teams as illustrated on figure 6. The first committed team is CMIC[5] team whose role is to acquire information on involved products and their propagation. The plan also envisages the engagement of several FPT teams whose objective is to slow down the progression of the gas cloud using water walls and to protect tanks by sprinkling them. This requires water resources and material (water pipes, reels...) this is why the intervention of a reel cell is also designed to provide these resources. All these teams are made up from three to five members and for each one of them there is a handbook describing the whole of the procedures which it can be led to carry out. All these teams derive from the models defined in *MASCARET*, as figure 7 shows for the example of a FPT team. Thus, in this example, FPT team inherits the `TEAM` class of *MASCARET*. This creates three team roles (Chef (*Head-Master*), Sous-Chef (*Second Head*) and Servant (*Helper*)) inheriting `TeamRole` and defining actions such as `SeTenirPret` (*Get Ready*) and `BasculerLaFleche` (*Manipulate Reel*) inheriting `GDAction`. The work of the designer in *SecuReVi* is thus primarily to implement these elements while inheriting *MASCARET*.

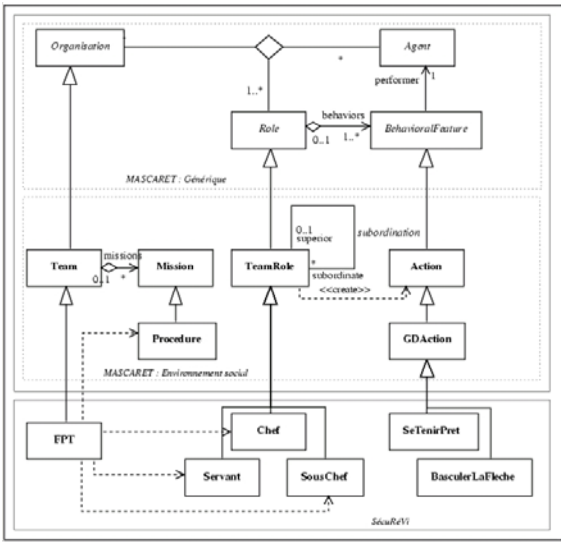

Figure 7: Team reconstitution.

According to the exercise's scenario, these organisational structures can be created at the beginning of simulation or in a dynamic way. Organisations are then FPT or CMIC teams (team FPT n°1, team FPT n°2, team CMIC n°1...). For each team instance, the roles (Head, Second Head...) are also instantiated. On the other hand, in the case of firemen, agent assignment to roles is described in the scenario, each agent knows, from the beginning, in which instance of team it plays

[3] Fire engine Thunders Pumps
[4] Vehicle for wounded persons

[5] Intervention Chemical Movable Cell

and which role it plays: it is the real operating mode of firemen. For each agent taking part in a team the actions defined by roles are then created. Teams also define missions which are described in firemen teaching documents. Each one of these missions is instance of `Procedure`, they are instantiated during the creation of teams, but the transfer in agent's knowledge is effective only during the execution of one of them.

8 Pedagogical use

Learners play the roles of various heads of groups intervening during the incident and trainer takes part in simulation to cause dysfunctions, to help learners or to play a role in a team. Learners must then follow an intervention plan, order the realization of procedures to groups and bring back the situation to their chief.

The pedagogical use of *SecuReVi* is not yet completely formalized, but there is undoubtedly a phase of design of elements being able to intervene in exercises, a phase of design of scenarios, simulation and debriefing.

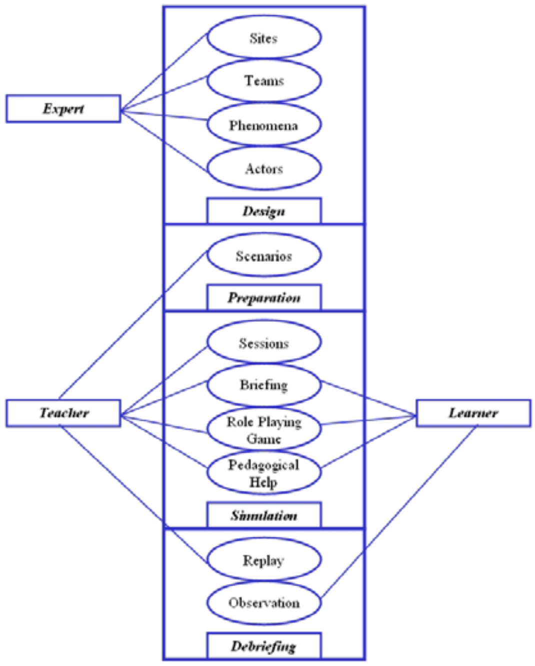

Figure 8: Pedagogical use case.

Three roles (expert, trainer and learner) are involved in the teaching use of *SecuReVi* which proceeds on four phases (Figure 8). The first phase is the design of elements which can play a part in exercises. It is a question of conceiving physical phenomena and teams of firemen; it is the stage which we previously presented for the exercise of gas leakage. This phase needs an expert (or a group of experts) having competences in model *MASCARET*, programming and the specific model field: chemists, physicists or meteorologists for the physical phenomena and officers firemen for the operating teams.

The second phase is carried out by the trainer, according to elements provided by experts (organisational structures and types of agent), it describes exercises or scenarios. It is the instantiation of organisational structures and assignment of roles to agents. A scenario also includes situations by which the trainer wants that learner passes, these situations are represented by events which can be broadcasted in the environment or be addressed explicitly to one of its agents so that it causes this situation.

The two last phases are simulation and debriefing; they involved the trainer and learners. During this phase all the exchanged actions and all messages are dated and recorded to be useful during the debriefing. This last phase was not formalized, but the traditional functionalities awaited during this phase are the capacity to *re-play* the simulation.

9 Conclusion

In this article, we show how the model *MASCARET* is applied to *SecuReVi* intended for training of firemen officers. This virtual environment for training allows realistic simulation, first of the physical environment made up of factories site and physical phenomena such as the propagation of a gas cloud and the effect of a water jet, and secondly, social environment represented by firemen teams. The design of *SecuReVi* holds in the description of organisational structures and agents based on those proposed in *MASCARET*. Thus to conceive the physical phenomena described in *SecuReVi*, the designer bases himself on the interactions networks and the reactive behaviours. To design the teams of firemen as for describing the missions and the actions carried out by their members, it is necessary to derive from the concepts of team, mission and action of *MASCARET*. The pedagogical use of *SecuReVi* is articulated around three roles. The expert is the designer of the organisational structures as well as agents who can take part in it. The teacher writes the scenarios of the exercises starting from these elements by creating organisational structures. He also takes part in simulation to generate dysfunctions or on the contrary to bring a pedagogical help to learners which play roles in the teams created. The *SecuReVi* application adds up approximately ten agents "characters" and a thousand of "reactive" agents. It seems difficult to use *MASCARET* to conceive applications requiring a very great number of agents "characters", but note that *MASCARET* is intended for the design of virtual environments for training in which it seems impossible that learner can deal with several hundreds of characters having all a different rational behaviour. If however this great number of characters must be simulated, they would then be gathered in more significant entities (teams, battalions...) which would control their behaviour.

In *SecuReVi*, pedagogical functionalities awaited classically in a virtual environment for training, were not formalized. The study of various environments for training shows that *MASCARET* is a solution which makes it possible to implement the functions present in the existing environments and which offers mechanisms making it possible to improve them. Indeed, virtual reality and multiagent systems seem interesting for the realization of scenarios and “settings in scene” which, according to [Cra99] improve the implication of learners in simulation. Moreover, the approach that we choose to simulate the virtual environment makes it possible to distribute the realization of these functionalities in the environment and to use the avatar to implement the pedagogical helps such as assistance or demonstration. Indeed, this one has sufficient knowledge to create the student’s model and to compare it with that of the expert. The experience feedbacks of the *SecuReVi* application will enable us to formalize these pedagogical functionalities. This work is planned right now within collaboration with the civil safety services of Brest, the National Institute for Studies on Civil Safety (INESC) and the Laboratory of Industrial data processing of the National Engineers School of Brest.

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