A GOAP Architecture for Emergency Evacuations in Serious Games

César Garcia-Garcia, Laura Torres-López, Victor Larios-Rosillo, Hervé Luga
CUCEA-Postgraduate and Research Department
Univérsidad de Guadalajara
Periferico Norte 799, Guadalajara
Mexico
cesar.garcia@cucea.udg.mx

ABSTRACT: *This work presents the current development of a Goal- Oriented Action Planning Architecture to be used in the DVRMedia2 Framework AI Engine. The purpose of this research is to model complex behaviours to be used for massive simulations, with thousands of virtual characters acting in a congruent manner in emergency situations, where first responders and civilian population could be senzibilized and trained.*

Keywords: Serious Games, Behavioral Animation, Crowd Simulation, Distributed Virtual Environments, First Responders

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1. Introduction

When modeling non-player character behaviour for any game, one way to obtain realism is the use of action planning schemes [5, 7, 11, 12] that incorporate perception of the environment and goal selection.

In this context, we are dealing with a serious game where emergency evacuations can be simulated to sensibilize and train the general civilian population as well as the first responders.

1.1 Behaviour modeling

To effectively model crowd behaviour, it is necessary to first model individual behaviour that is coherent with the simulated virtual environment [16]. In order to behave in a believable way these artificial actors must act according to their surrounding environment, being able to react to environmental changes and also to the actions of human-operated avatars in the virtual world [18].

Reactive behaviours, such as adapting to the changes in the environment, are not enough to create realistic autonomous actors. Creating realistic behaviours also demands the representation and manipulation of the perceived information [15]. This is what we call *cognitive behaviours* and once integrated to the reactive ones, we can truly speak of complex behaviour.

Once the individual behaviours are realistic, a multi agent system could be used to replicate the individual into crowds, this however, creates an homogeneous crowd behaviour that might or not appear realistic.

1.2 Psychological Factors
Psychological or *human* factors in behaviour that have been considered for crowd simulations are part of the artificial actors' *internal state* which provides certain degree of individuality and also reflects differences in perception and emotion, such as fear [13], hunger [15], tiredness [4], etc.

These variations provide the actors with realistic behaviours under emergency conditions, enabling the sim-ulation of panic situations where real people are unable to act due to fear. Also, certain behaviours are tied to specific internal states, limiting their execution to predefined levels of said state. In this manner we can simulate an stampede when fear overcomes the crowd.

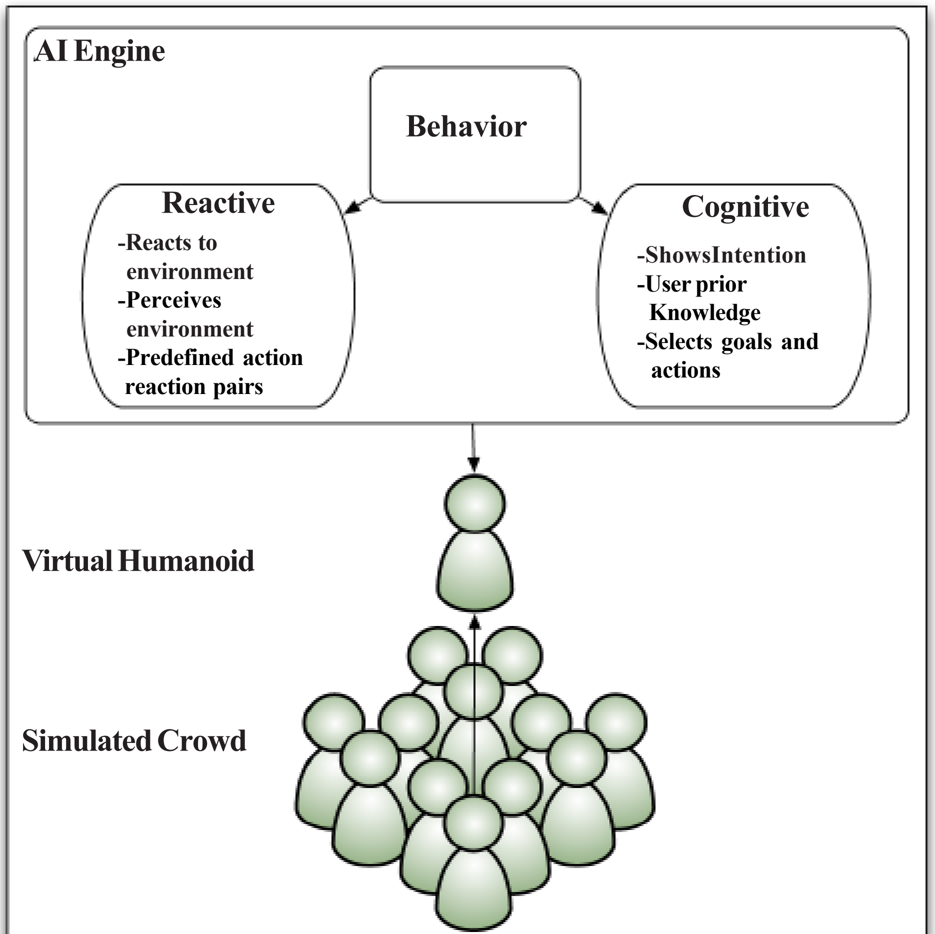

Figure 1. Behaviour Structure

2. Conceptual Brain Model

The conceptual model for the artificial brain shown in Figure 2 includes the following modules:

2.1 Perception Module
The perception module contains the information that is available to the artificial actor about his environment through his senses. This includes what the actor can "*see*"– such as the place where he is and threats present– and what he can "*hear*"– such as other actors in the same area.

To effectively store this information it is divided into three different substructures: region information contained in the database

[17]; Voronoi neighbors [8]; and perceived threats [13].

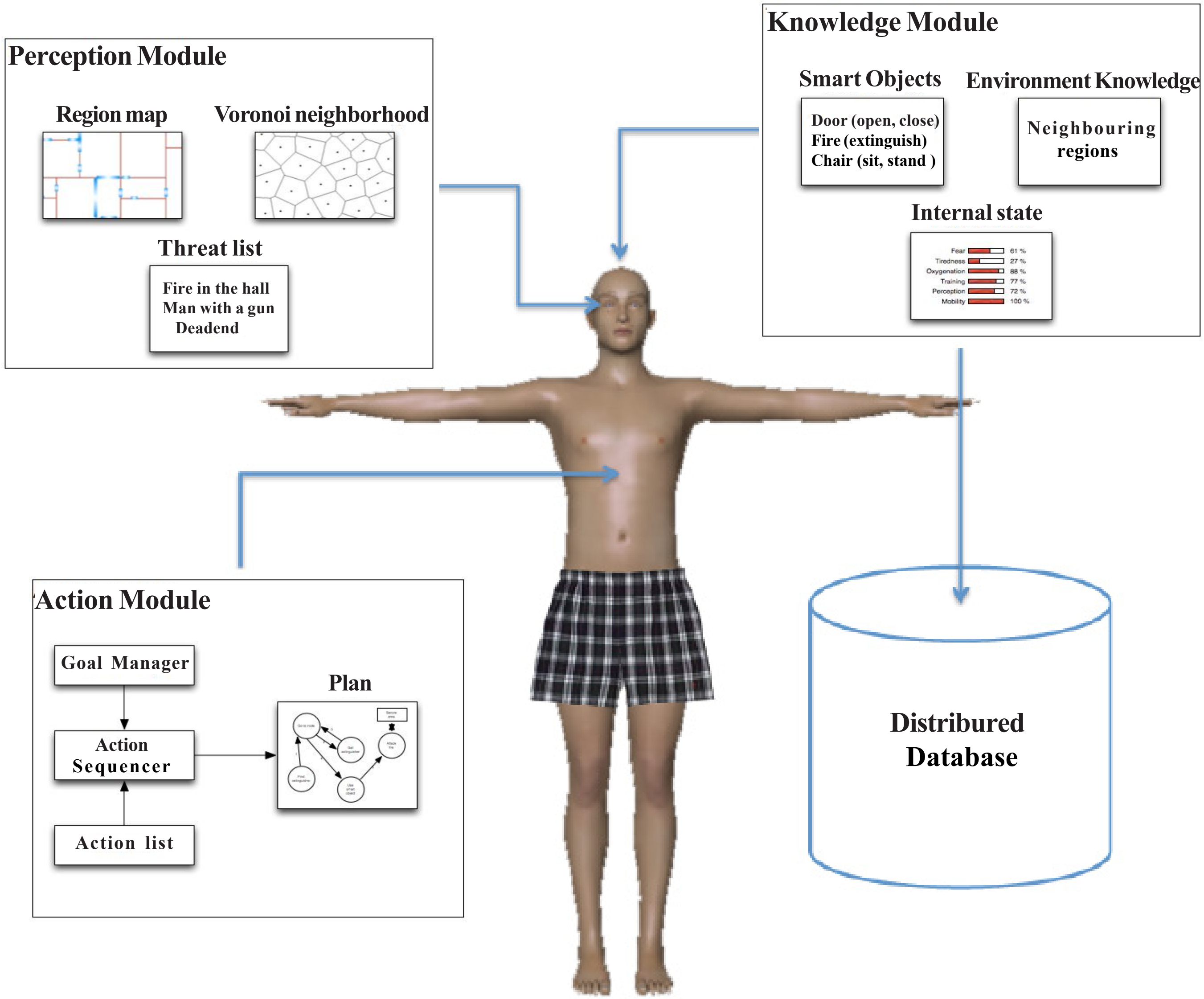

Figure 2. Brain Architecture

The perception module represents what is available to the senses all the time and as such it gets updated every simulation cycle with fresh information. In later parts of this work the perception module will also handle virtual actor communication, such as sharing threats with other actors and acquiring knowledge from them.

2.2 Knowledge Module

The knowledge module contains the information about the world that has already been internalized by the actor, as well as his own *internal state*. This also includes a set of *smart objects* of which the actor is aware and the regions to which the actor can move from the present one.

Smart objects announce themselves to the environment, as well as the actions associated with them. Those actions are then added to the individual actor's *action lists* and are available to the Action Module for their execution.

Knowledge of adjacent regions is also stored as knowledge, as it is not always available to the actor's senses, so he must "*remember*" where he has been as well as the places he can move to.

2.2.1 Internal State

The internal state deserves a more detailed view as it is, along with the individual action lists, the basis of individual actor behaviour. The internal state represents the status of the actor as a series of values that influence its behaviour.

The values associated with the internal state are described as follows:

• **Fear:** The awareness to the presence of objectively identified danger or threat [6]. The longer the exposure and magnitude of the threats, the more this value grows.

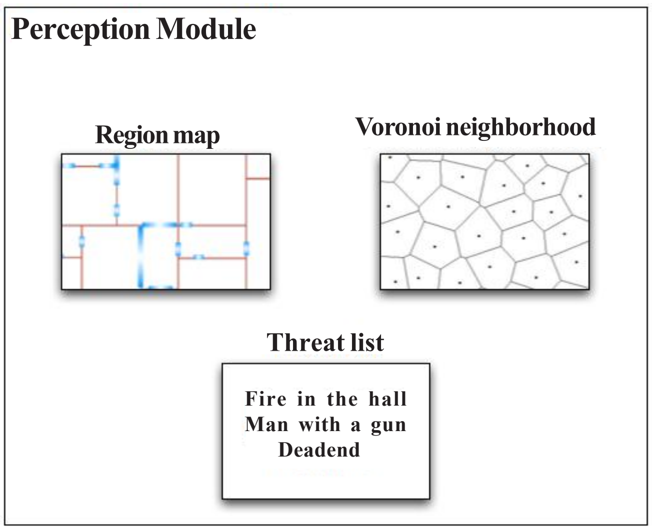

Figure 3. Perception Module

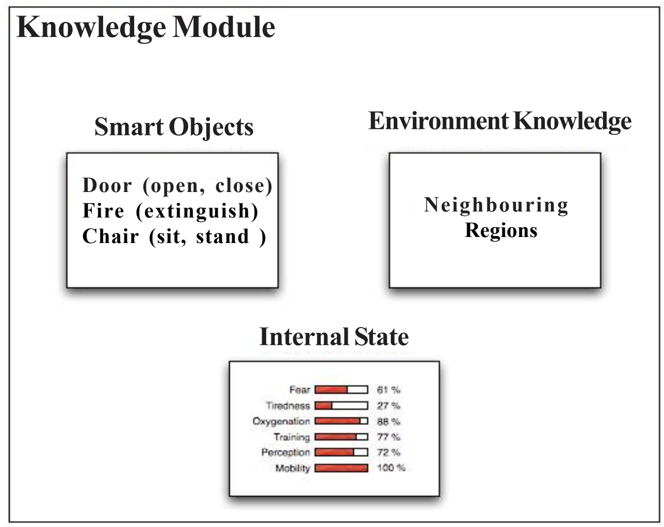

Figure 4. Knowledge Module

• **Tiredness:** The ability of the actor to undertake certain strenuous activities like running, using a fire extinguisher, climbing a ladder, etc. Each such action taken will make the actor slightly more tired, reducing his ability to perform.

• **Oxygenation:** The ability of the actor to breathe and oxygenate his body. This value will be reduced in the presence of specific threats such as smoke.

• **Training:** The amount of training and environmental safety awareness that the actor has. Certain actions require a minimum training to perform, such as the correct use of the fire extinguishers.

• **Perception:** The ability of the actor to perceive and understand his surroundings. This ability will be impaired by certain threats such as smoke, which reduces visibility.

• **Mobility:** The ability of the actor to move around his environment. Certain threats such as flooding can reduce mobility and this will also be useful when modeling people with disabilities and other special needs [2].

Certain specific goals and actions will only be included in plans when the actor's internal state reaches certain thresholds, for example, a character will panic when his *fear* has reached a certain value.

There is also a relationship or hierarchy in which the internal state's values are to be recalculated, as proposed by [4]. This relationship, called *behavioural network*, also reflects how internal state values influence other parts of the artificial brain.

2.3 Action Module

The action module handles the decision-making processes of the virtual actor. This includes assigned or desired goals which the actor must accomplish; a list of actions available to accomplish the goal and an action sequencer or *planner* that combines actions to fulfill goals. Once a valid action sequence or *plan* has been created, it is stored for its step-to-step execution.

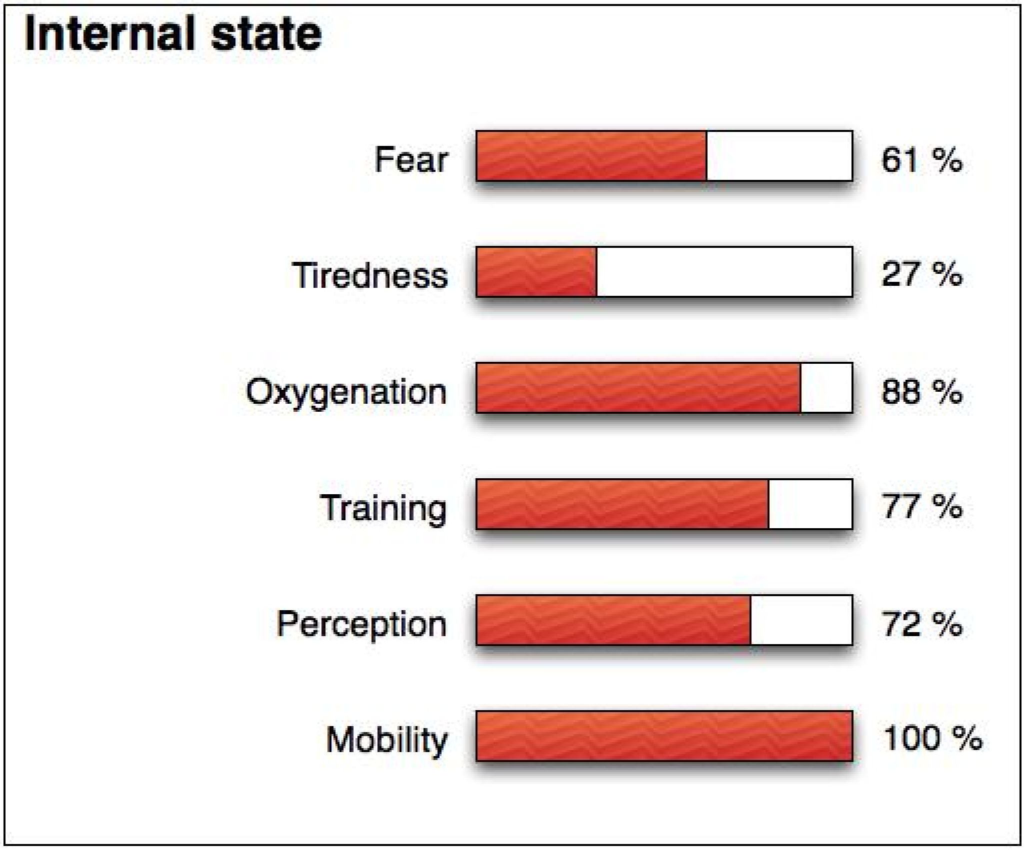

Figure 5. Internal state of the artificial entity

A *goal* is any condition that the actor wants to satisfy [9], or a specific state of the virtual world, which can be composed as a set of conditions, that the actor needs to reach. For example, the **SecureArea** goal implies that the virtual actors must eliminate any threats to the best of their abilities, that is, using only the actions available in their action lists.

The action lists, as per [10], represent the different actions available to a Fireman, a Trained Civilian and a- implicitly untrained Civilian. When the **SecureArea** goal is fed to the Action Sequencer each different actor will create a different plan containing their available actions:

• **Fireman:** The fireman will include his **AttackFire** action to repeatedly attack the fire until it is put out or another goal takes precedence.

• **Trained Civilian:** The trained civilian will include his **Attack Fire Once** action to use an extinguisher on the fire, then evacuate orderly.

• **Untrained Civilian:** The untrained civilian, having no available actions to deal with the fire, will use his Run action to secure himself, as he is unable to secure the area.

In the specific case of the Fireman, his action plan might first need to find a fire extinguisher, go to it, grab it and then come back to the fire and use the actions made available by the extinguisher smart object to attack the fire and satisfy his **SecureArea** goal.

3. Current Work

We are currently using the JMonkey Engine [14] to develop a serious game where we can sim- ulate evacuations of massive structures such as stadiums, shopping malls, government offices, industrial complexes, etc. While JME is a good choice for our graphical needs, an additional communications layer, based in the JADE [3] is also being imple- mented. This layer will also allow for the distribution. of the goal management and plan generation aspects of the conceptual brain model.

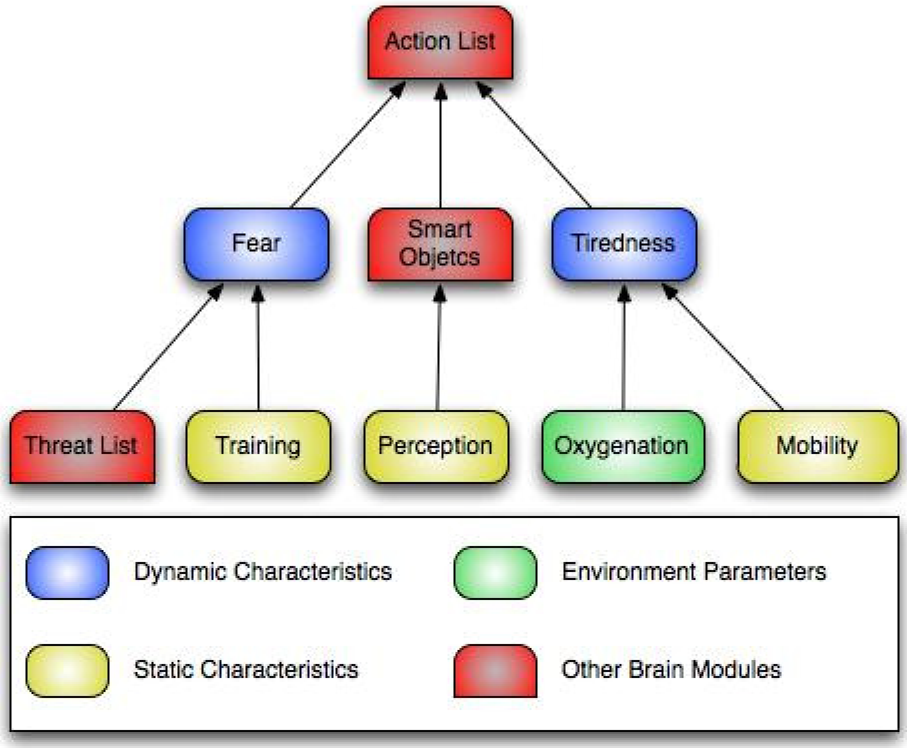

Figure 6. Behavioural Network

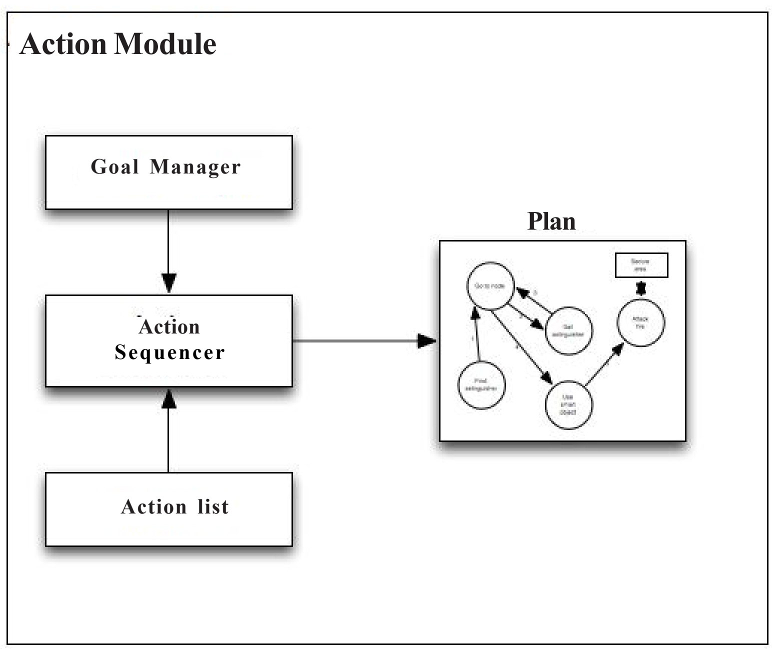

Figure 7. Action Module

Adding this layer, we can have a game-manager agent controlling the JME graphical interface while also providing other fundamental agent-related benefits such as communication and mobility. Each agent will contain an implementation of the proposed brain, which in turn will control an artificial entity in the graphical environment. Our tests suggest that this game-manager agent does not severely impact graphical performance.

As proof of concept, we generated different crowd sizes using other agents in the same container beyond the game manager or "*peer*" agent. Given that we are working with a serious game, we decided to test the following variables that we consider important for a game: CPU usage, Memory usage and Frames per second or FPS.

As seen in Figure 8, our results show that even when running 2500 agents, the graphical performance did not suûer from quality loss, and that the real limit was the Virtual Machine's inability to launch additional threads.

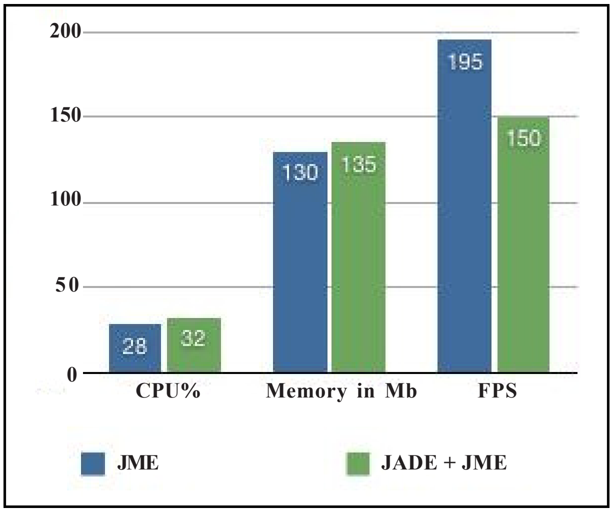

Figure 8. Comparative performance when running JME only vs. JADE-managed JME

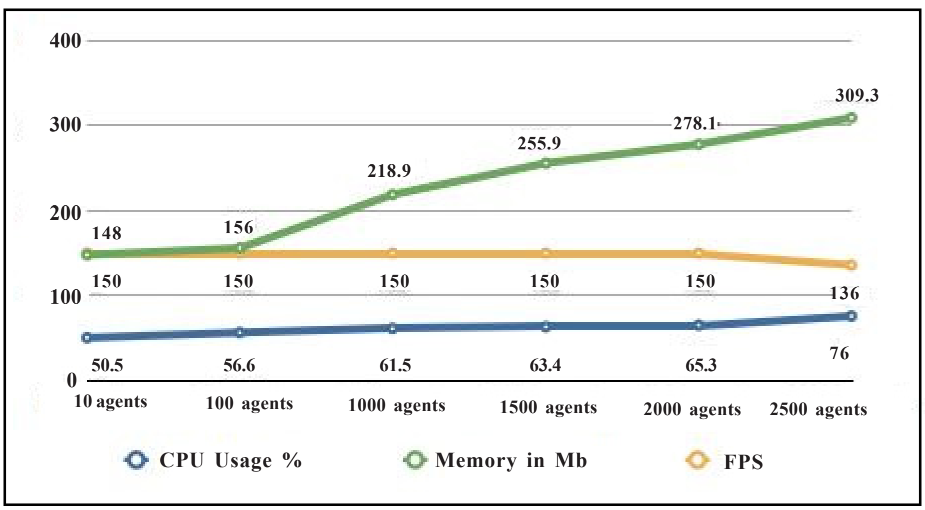

Figure 9. CPU, Memory and FPS performance during simulation

3.1 Hardware Specification

All tests were performed on a MacBook Pro 2.26 GHz Intel Core 2 Duo Processor with 4 Gb of RAM, running Mac OS X 10.6.4. Using Java ver. 1.6.0 with maximum heap size set to 1024 Mb. We are using a NVIDIA GeForce 9400M graphical card with 256 Mb in VRAM.

4. Conclusion and Future Work

We find the current results promising and will continue to develop in this direction, adding modules as part of the agent's behaviours as they are developed and using the obtained values to optimize the maximum number or agents that should be running per peer in a large scale simulation.

The generated behaviuor model and AI engine could be used, as part of the DVRMedia2 framework, to simulate evacuation of massive structures such as stadiums, shopping malls or education facilities in the region holding over 1000 personnel.

4.1 Experimental prototype
It is highly desirable to use a detailed environment that is representative and easily recognizable by the general population in this case, the "*Gimnasio de Usos Multi- ples in Unidad Revolución*" shown in Figure 10 with a capacity for 600 people, where actors can behave in day to day situations but also simulate evacuations.

As part of the bigger project, the first working demo will be the evacuation of a simulated stadium in the context of the 2011 Guadalajara Panamerican games. This will be a great opportunity to demonstrate the crowd generation, communication, behaviour, distributed processing and database capabilities of the DVRMedia2 Frame- work.

Future work in this research includes escalating our quasiexperiments to a High Performance Computing environment, such as the cluster-around 1.3 teraFLOPS- being used to test network capabilities in other modules of the project [8]. Such implementation will be able to deal with bigger crowds in emergency evacuations, working with around 40,000 entities for the larger soccer stadiums in the region. Also, we will have to validate the data distribution architecture being used [17].

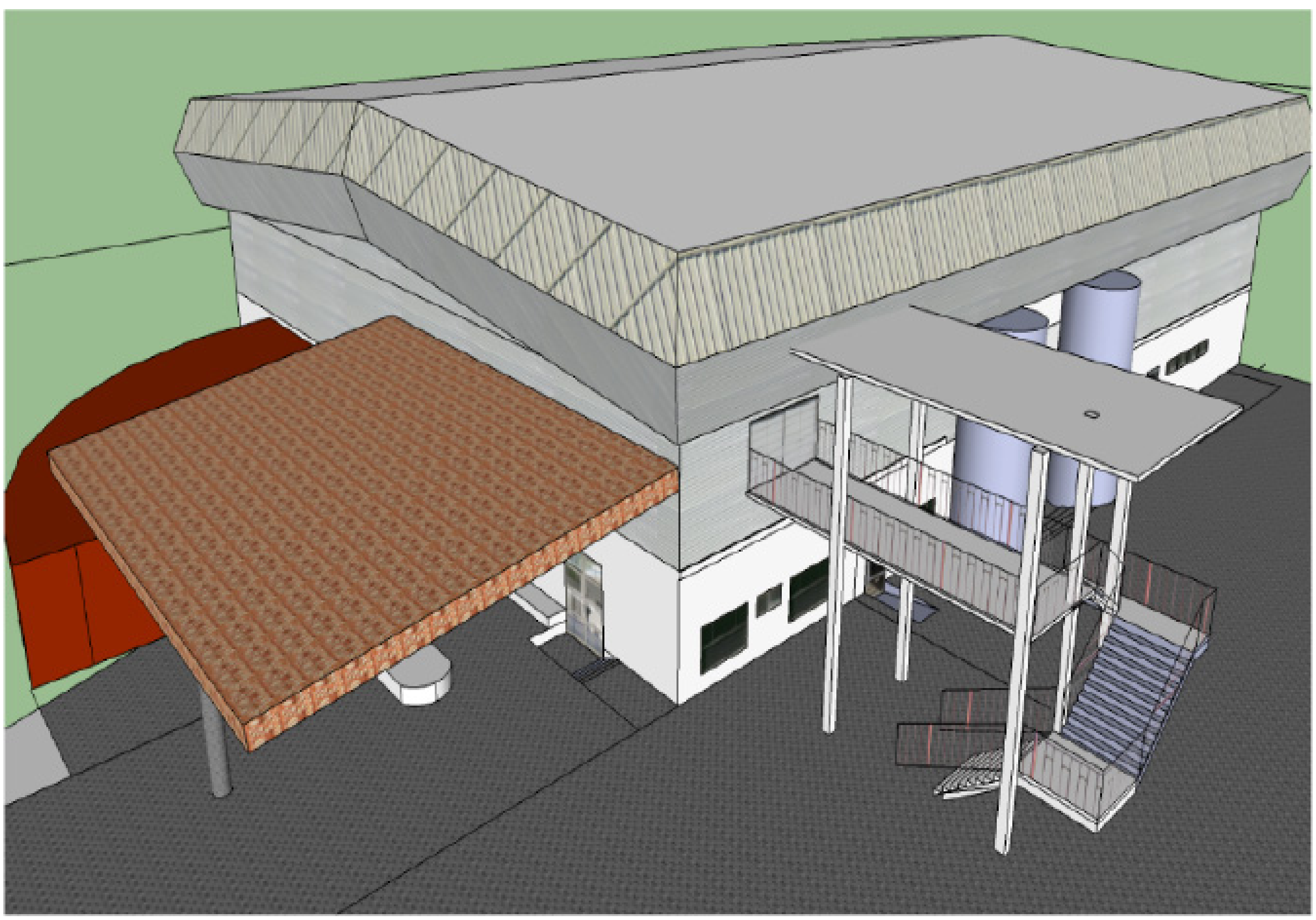

Figure 10. The Gimnasio de Usos Multiples in Unidad Revolución will be one of the venues for the 2011 Panamerican Games

5. Acknowledgements

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