GRAPHIC SIMULATOR FOR ADVERSARY ADAPTIVE AGENTS IN WAR ENVIRONMENTS WITH REAL TIME PARALLEL PROCESSING

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ABSTRACT

The presented paper is part of a prototyping effort in the sense of searching solutions for combat systems, where through the use of virtual reality and feedback control techniques is provided a real time aircraft decision system for an operational combat environment. Using virtual reality to develop the prototyping and simulation for highly complex systems is quite advantageous, once that it provides an appropriated system follow up with lower cost and higher safety.

Keywords: virtual reality, visualization, parallel processing, autonomous adaptive control, real time systems.

1. INTRODUCTION

The analysis and implementation of autonomous agents is a challenge and motivating field of science, which has in recent years considerable interest grow in system design for military operations as a significant component for simulation of real time systems, where uncertainty parameter has to be estimated in real time due the adversary actions in a specific saving mission. We simulate a combat scenario where independent agents need to correspond to each opponent reaction, in the sense of inferring dynamically the parallel adversary plans during the combat mission. Every agent will be corresponding with a payback reaction, trying to minimize the probability of the success his opponent.

A large range of works could be found in virtual reality and autonomous systems using real time and parallel processing approach applied to simulation with its focus on intelligent models for automation of real time problems, visualization and combat simulation. Henderson [Henderson00] developed a virtual environment focusing on training simulation systems for US Naval operations, incorporating the military performance measurements for each training combat case simulated. Tischler [Tischler99] has developed a multidisciplinary flight control environment, to ensure desired performance handling intended qualities to minimize flight-test to ensure desired performance, incorporating high requirement for combat helicopters simulators. Simiakakis [Simiakakis01] presented parallel processing as a suitable technique applied to obtain a good speed-up and to efficiently balance the load between the processors while minimising the required memory per processor in computer graphic visualization. Silva [Silva01] has used parallel processing and computer graphics for the visualization of an industrial adaptive control simulation as a framework for control specification prototyping.

2. VIRTUAL ADVERSARY AGENTS

We present a new framework for construction and validation of stochastic autonomous systems, where through the use of adversary agents is possible to achieve a well tuned validation of any system under study, with its follow-up and visualization in real time with a virtual environment. The methodology was adopted as a suitable approach to demonstrate the effectiveness of models that have to react dynamically within stochastic events, where external agents in parallel try to damage the stability of some adaptive control rule. To synchronize dynamically the agents simulation and graphic visualization with the processor in real time, we used parallel processing, implementing a fitted synchronization between the graphic and adaptive agents in combat. At this point, a fair approach system architecture has to provide for the adversary adaptive agent equivalent conditions, i.e., that each one agent will be informed about the last step action of his opponent, in the sense that an equal priority on information access is established, providing a good conditions for a tactic damage or protection reaction in feasible time.

2.1 PROBLEM REPRESENTATION

We will leading with the simulation of a combat field where aircrafts compete against each other trying to save or to destroy the populations surviving probability in determined geographical areas. The scenario is composed by 39 cities involved in battle fields, where each city maintenance stock will be serving as a main goal for our agents, in the sense that depending on the state of such stocks will be the probability of success to each related group. Reacting dynamically with the adversary agent in real time will require a model which should provide a fast answer, in order to address the best decision for our system even if it needs to react in an emergency situation, where the system would be required to generate a new action plan that has to react against any unexpected adversary action. For the conception of our model, such situation is expressed by penalties on the results processed in the objective function. On the other side, a real good adversary will be designed to try to promote as much as possible damages in our adaptive agent function.

Math model for the adaptive agent:

$$\max f(x)^t \quad (1)$$

$$f(x)^t = \sum_{t=1}^{n}\sum_{i=1}^{m} v_i(x)^t - \alpha_i g_i(y)^t + \psi_i h_i(y)^t \quad (2)$$

$$g_i(y)^t = \lambda h_i(z)^{t-1} + \wp s_i(z)^t + P(h_i)^{t+1} \quad (3)$$

$$h_i(y)^t = \gamma g_i(z)^{t-1} + \delta z_i + P(g_i)^{t+1} \quad (4)$$

$$P^{t+1} = P^t\left(z_i, \frac{\sum_{t=1}^{t}\sum_{i=1}^{m} w_i(y)^t}{\theta}\right) \quad (5)$$

$$\sum_{t=1}^{n}\sum_{i=1}^{m} g_i(y)^t \le C^t \quad (6)$$

$$\sum_{t=1}^{n}\sum_{i=1}^{m} h_i(y)^t \le D^t \quad (7)$$

$$z \approx N(\sigma^2, \mu) \quad (8)$$

$$w_i \in \{g_i(y)^t, h_i(y)^t\} \quad (9)$$

$$\alpha_i \in \{0,1\} \quad (10)$$

$$\psi_i \in \{0,1\} \quad (11)$$

$$s_i(z)^t \begin{cases} x_i^t < x_i^{\min} & \Rightarrow \quad z^3 + \Delta \\ x_i^t \ge x_i^{\min} & \Rightarrow \quad z + \Delta \\ x_i^t \ge x_i^{\max} & \Rightarrow \quad z^2 + \Delta \end{cases} \quad (12)$$

where

$\alpha, \psi, \lambda, \wp, \gamma, \delta, \theta, \Delta$: tuning parameters.

i, t:	respectively city and time.
x:	provisions level in the city i.
y:	input/output into the system.
z:	input/output adversary onto the system.
w:	forward provisions level on city i due the adversary action.
f(x):	sum of provisions level in each city.
v(x):	provision volume in the city i.
g(y):	adversary damage on city i in time t.
h(y):	reaction for the city i for the time t.
s(z):	penalty function.
C^t:	upper bound for adversary attack in time t.
D^t:	upper bound for adaptive agent defense.
p:	correlation between z performance and desired provisions level in reaction to adversary agent.
z:	provisions into the system.

Math model for the adversary agent:

$$\min Q(f(x)^t), \qquad t = 1,\dots,n \quad (13)$$

where

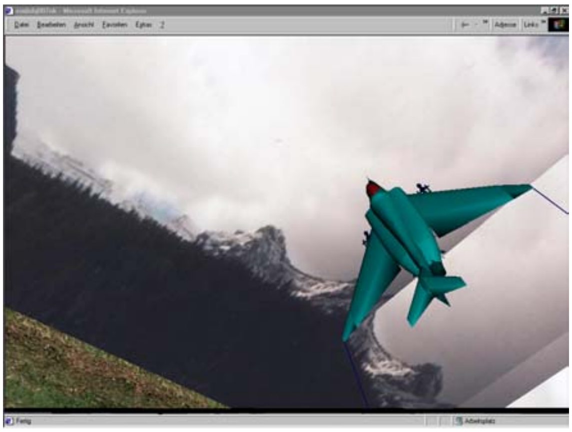
$Q(f(x)^t)$: objective function for the adversary agent.

The effectiveness of the adversary agent action is related to its damage on function objective of the adaptive agent, as shown by its highest profit in equation 13 with the minimization of the correlative value for the equation 1.

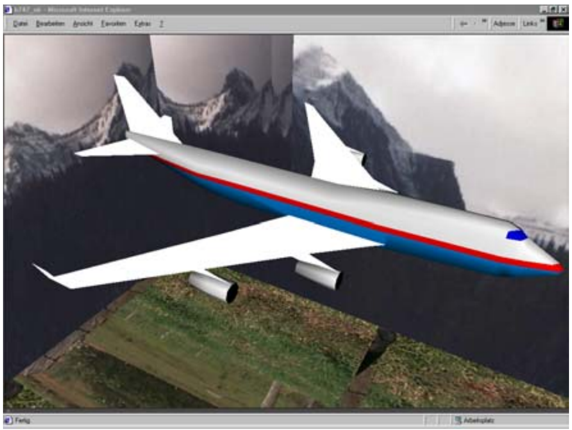
The routing problem has been solved through a heuristic method, where the nearest next path is choosed to be performed by the agent attending a well defined city priority list, it trying to minize the time required to help some city under attack.

2.2 VIRTUAL ENVIRONMENT

The key design goal in the development of our interface was to assist users in effectively visualizing, and hence interpreting the performance of the adaptive adversary agents as a suitable way to validate complex systems that will be required to operate under a large range of uncertainties in real time. Hence the amount of multivariable data generated by such simulation could be visualized in real time, providing for the user a better insight onto the model performance in study with a feasible immersion into the virtual environment through the simulation visualization in 3D, as shown in figure 1.



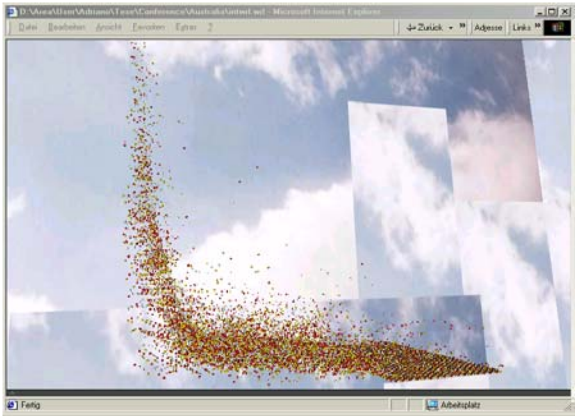
(a) adversary agent in attack



(b) adaptive agent in mission
Figure 1

Moreover the 3D simulation visualization, the visualization of a set of most import events on the control model need to be studied and well predefined, to provide an useful accompanying on the possible weak and vulnerable points in the combat system under analyses, such as how the agent is reacting due adversary attacks. As we have observed in figure 2, the most results stay on the middle point, it caused by the conflictive multi goal force generated on the combat between both adversary agents. Other design issue was a decision on the hardware and software suitable to the implementation. For pragmatic reasons, we decided to use the widely available PC platform and to use standard input devices, such as a mouse and keyboard, for the user initial virtual environment interaction.

Furthermore the addition of a third dimension certainly adds new issue that has to be supported [Kobayashi00], the foremost of which is user navigation with the virtual environment. In order to simplify the navigation, in our application we allow the user a well defined degree of freedom at movement: the camera can change its elevation angle with respect to the horizon in the y axis in a predetermined range of options, and the user can fly through the entire virtual world defined by the upper and lower x, y and z axis values.



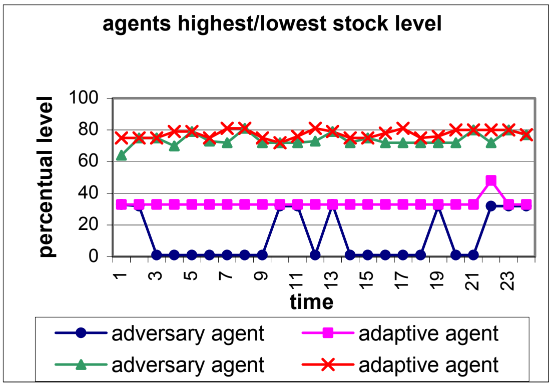
Mathematical behaviour
Figure 2

For the virtual environment was used the following software: to 3D modelling we have used the software MilkShape3D, while the user interface was developed with java3D; such approach was taken thinking on the facilities provided through the internet. The adaptive control simulator was wrote in C++, so the link between C++ and Java was done using a set of function resources from each programming language which assures the communication between these distinct programming languages.

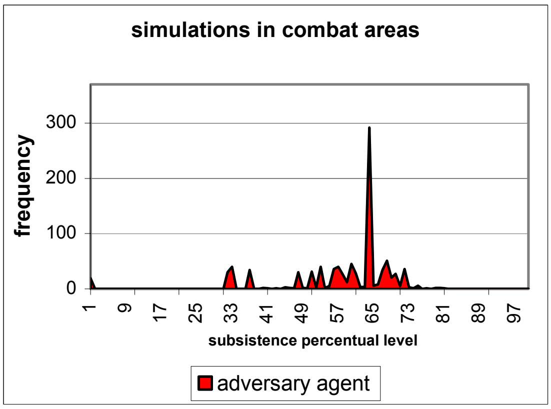
3. SIMULATIONS

The model performance has demonstrated how well fitted react the self-adjust on the adaptive agent, once that it has always responded with a positive reaction in real time due each parallel adversary attack. Although the adversary agent has tried as much as possible to damage the maintenance levels for every city in order to result in lost of lives, it represented by a stock negative level, the adaptive agent has responded accurately even when the adversary agent has promoted critical stock levels. See figure 3 with a 24 hours simulation depicted.

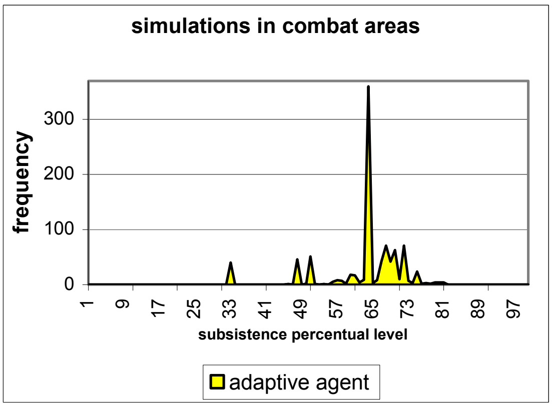
As we could observe also in the histogram depicted in figure 4, the maintenance level is influenced up and down on each action performed by the agents. The critical parameter negative stock level, although it is insistently tried to be achieved by the adversary agent, the adaptive agent should keep control of such situation with a suitable immediately reaction. As depicted, the greatest damage resulted from the adversary agent has achieved the subsistence level to 1% of the city stock capacity, but it resulting in an immediately reaction from the adaptive agent.



Adaptive reaction
Figure 3



(a) Histogram of adversary agent



(b) Histogram of adaptive agent

Figure 4

4. CONCLUSIONS

The presented work has intended either to elaborate a customized three-dimensional environment for simulation visualization and to postulate the use of adversary agents as a systematic way to improve the performance of applications for real-time systems required to operate under a large range of uncertainty. The use of virtual environments could provide an efficient approach to the visualization effort addressed for a better insight of high complex system simulations. The visualization of mathematical performance could improve the robustness and the adjustment of models parameters with its visualization in real time, customizing and decreasing time and cost related with system prototyping.

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