A Scenario-Based Virtual Environment for Supporting Emergency Training

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ABSTRACT

Simulation exercises are particularly popular for training in emergency situations. Exercises can vary in their degree of realism, complexity and level of stress, but they all try to reproduce a scenario of a real emergency so that each participant simulates the actions carried out for the role they should play. They not only support effective and situated learning, but they can also serve to improve the plan by allowing the identification of weak points and potential drawbacks in it. To facilitate the design and implementation of 3D virtual environments in which training exercises can be conducted, in this paper we propose to use the Cross-Impact Analysis technique in combination with an educational game platform called GRE. We also present a Simulation Authoring Tool that allows the designer to carry out the integration of the knowledge captured by means of Cross-Impact into the game designs that GRE can interpret.

KEYWORDS

Emergency Training, Scenarios, Cross-Impact Analysis, Virtual Environments, Serious Games.

INTRODUCTION

The use of 3D virtual environments for conducting training exercises can provide numerous advantages such as flexibility, relative low cost given a midterm horizon and large scenario development capabilities. However, their adoption in practice is not as widespread as might be expected due to the difficulties associated with their design and development. The designers not only have to deal with the inherent technical complexity of designing a 3D virtual environment but they also have to be able to represent realistic situations and different action paths that can support the training processes. There are various software tools that support emergency management staff providing a greater or lesser degree of immersion in virtual scenarios, for instance ArtesisVirtual (Houtkamp and Bos, 2007) and ADMS-COMMAND ™. However, most of these products restrict training to one or more specific emergency situations and settings, while making reuse of training in other settings is rather complicated and expensive. It is therefore important to design emergency services training software tools for Emergency Planning, which are highly configurable, easy to use, and capable of reproducing different scenarios (Aedo, Bañuls, Canós, Díaz and Hiltz, 2010).

In this paper we propose to use scenario generation tools in combination with serious games to obtain 3D virtual environments in which simulation exercises can be conducted. More specifically, we propose to use Cross-Impact Analysis (CIA) (Turoff, 1972) as a scenario generation tool for an Education Game (EG) platform called GRE (Game Rules and scEnario). On one hand, CIA is a powerful scenario generation tool optimized for flexible and high-speed calculations support, and it has already been used and validated as a base of planning games (Hendela, Turoff and Hiltz, 2010). On the other hand, GRE is a platform able to interpret XML files containing descriptions of EGs specified in terms of elements of the GRE model (Zarraonandia, Díaz, Aedo and Ruíz, 2014), and to automatically generate a virtual environment in which the game can be played. We present a Simulation Authoring Tool that allows the designer to integrate the elements of CIA in the game definition, so that plays of the game can be used as training exercises.

THE GAME ENGINE: GRE PLATFORM

With the aim of accelerating the development process of an EG and to minimize the technical assistance required in this process we use the GRE Platform: a system able to interpret descriptions of EGs expressed in XML files and to generate 3D games based on them. These descriptions follow the schema of the GRE Model (Game Rules & scEnario Model) presented in (Zarraonandia et al, 2014). The GRE Model organizes the game features most often regarded in the literature as significant in producing an engaging, fun and educational game experience, as for instance clear goals, feedback, socialization, storyline, interaction, etc. Most of these features are defined around the concept of game entities and events. Entities are described through their attributes and the actions that they can perform, and are linked to graphical models that represent them in the game scenes. Events occur as a result of the interaction of the game entities, and can trigger the activation of feedback, objectives achievement, game failures or rewards, for example. For each of the features considered in the GRE Model we defined a set of configurable elements and a basic vocabulary that the GRE Platform will be able to interpret. The platform processes game designs expressed in XML language using this vocabulary, and generates the corresponding game following a process that involves four main steps. In the first step the game scenes are generated by adding to them the graphical models referenced s in the XML file at a specified size, position and the texture. In the second step the game logic is implemented by setting up the data structures that maintain the entities' attributes and states, and the programs (listeners) that monitor and detect the occurrence of the events specified in the design and trigger its outcomes. At present the platform is able to set up listeners based on entities' current positions, thresholds of attribute values, collisions and the triggering of actions, among others. Next, the rest of game components, as interface and controls, are configured. Finally, a monitoring service is set up and activated, in order to retrieve and store the information about the plays that the designer wants to record. The GRE Platform has been implemented using the Unity 3D Engine (Unity Technologies, 2013) and, at present, is limited to single player EGs.

simulation algorithm: cross-impact analysis

The simulation algorithm is based on CIA. CIA is a methodology developed to help determine how relationships between events may impact resulting events and reduce uncertainty in the future (Turoff, 1972). In the last years it is has been successfully applied in EM contexts for supporting planning processes (Bañuls, Turoff and Hiltz, 2013; Lage, Bañuls and Borges, 2013).

CIA FUNDAMENTALS

CIA deals with subjective probabilities that translate into causal relationships, notated as C_{ij} and G_i, with C_{ij} being the linear impact factor of event E_j upon E_i, and G_i being the linear impact factor of the events that are not specified in the event set upon the *i*-th event (Turoff, 1972). These resulting event sets do not follow a Bayesian relationship. Instead we are assuming they follow the Fermi Dirac Distribution in Quantum Mechanics (expression 1).

$$P_i = 1 / [1 + \exp(-G_i - \sum_{i \neq k} C_{ik} P_k)] \qquad (1)$$

According to the nature of the events we classify them into three categories. For a full explanation of the methodology see (Turoff, 1972; Bañuls and Turoff, 2011).

- **Dynamic Events (DE_i):** Dynamic events may or may not occur during a certain time period. Within such a time period, the factor measures we are estimating between E_i and E_j are considered valid.
- **Source Events (SE_i):** Source events are initial conditions that have already occurred before the beginning of the time-period.
- **Outcome Events (OE_i)**: These measure the results of the system that is being modeled at the end of the time-period.

SCENARIO GENERATION THROUGH CROSS-IMPACT ANALYSIS

In an EM context, the scenario definition process through cross-impact starts with the selection of a triggering event (natural or man-made) that causes the emergency (for instance a major wildfire). The scenario should include also context definitions that can be modeled through source events used to determine the initial situation of the scenario quantities or some qualities (e.g., defining degree of severity) within a scenario. These source events variables may express some sensible or limiting factors of the scenario being studied and can modify the way it should be treated or even how it is seen; thus scenario variables have the ability to change the characteristics of a scenario. The result of the estimates of professionals on the strength of the relationships between events C_{ij} is a model where every events initial probability of occurrence is .5., the zero point of likelihood for a *n* event to occur or not occur. It is possible to have players that take on human roles or even players that play the "mother nature" role so they are able to increase the likelihood and strength of a given natural disaster. The players can be allocated resources which can be translated as an investment in changing an initial .5 probability to higher or lower values. Only after everyone has had a chance of time period to make such decisions is the model triggered to determine the most likely outcomes in terms of all the specified events. One may include events that represent any phase of the situation including things like detection of particular threat type in the initial conditions (source events).

The scenario should also include dynamic events composed of both emergency and action events. The potential occurrences of emergency events (i.e. explosions, flood, fire, etc.) are not under emergency managers' control and are the cause of the crisis situation. The action events (i.e. search and rescue, fire response, communication, etc.) are decisions that could be carried out to respond to the emergency events (Lage et al, 2013). Finally, the outcome events are the results that will be estimated through the cross-impact model such as probability of success or total damages during the emergency.

ADDING IMPACT ANALYSIS TO THE GRE PLATFORM

Serious games can constitute a valuable tool for supporting the analysis of scenarios. They can provide visual representations of the elements analyzed, helping to comprehend/understand the current scenario situation and to better estimate the occurrence of future events. To use a game in this way it is necessary to match its elements with the ones of the simulation that it will represent.

Table 1 shows the proposed correspondence between the elements of the CIA framework, that support the description and analysis of the simulations, and the ones of the GRE model, that support the description of the game designs. As shown in the table, the initial conditions and the context of the simulation can be represented by the configuration of the game entities and their attributes. For example, in a simulation of a rescue and fire extinction operation the designers could include more or less instances of the entities that represent the victims, and to set up the attributes that represent their health to signify the seriousness of their injuries. In addition, the GRE model also includes a specific game component named "Context" for incorporating in the design images, videos and sounds that describe the context and atmosphere of the scenes of the game. Similarly, the different types of events that describe the simulation can be directly matched to some of the types of events considered by the game design model. This way, the source events can be implemented using random events with fixed probability. These events are triggered whenever the values of random numbers that the game engine generates periodically are greater than a threshold value between 0 and 100 associated with the event. With regards to the description of the dynamic events it is necessary to distinguish between emergency events and action events. The formers cannot be controlled, and their probability of occurrence increases or decreases depending on the occurrence of other events. As the source events they can be represented in the game by random events, although in this case their threshold values will not be fixed and must be updated whenever an interrelated event is triggered. On the contrary, the action events are controlled by the scenario actors as they are triggered by their own actions. Therefore they can be represented in the game by events triggered by the actions of the game entities. Finally, to implement an outcome event the game designers can make use of any type of game event that includes among its consequences the registration of the event occurrence in the platform monitoring and logging system. Thus, once the play concludes it will be possible to track their activation and assess the situation in which the scenario ended.

CIA		GRE Model	Description
Triggering event		Game entities: instances and attributes Game component: Scenario context	Context and assumptions.
Source events		Events: random events with a fixed probability of occurrence	Initial situation or starting pint of the training exercise
Dynamic events	Emergency events (uncontrollable)	Events: random events with a variable probability of occurrence	Cause of the crisis situation
	Action events (controllable)	Events: events triggered by the actions of the characters and game entities	Actions that could be carried out by the response team
Outcome Events		Events: events of any type (random, entities collisions, entities attributes thresholds...) set up as registered by the monitor service	Results for the system that is being modeled at the end of the training exercise.

Table 1. Correspondence between the CIA and GRE Model elements

GRE SIMULATIONS AUTHORING TOOL

The main objective of the GRE Simulations Authoring Tool is to allow the trainers the rapid definition of simulations based on existing serious games. This way, they can take as a start an existing game design, and modify and adjust its definition to obtain a new version that simulates a scenario evolution. To simplify the process the tool provides the user with a graphical interface to carry out these actions. In addition, it is built on top of the GRE Platform. This allows visualizing and testing the changes introduced in the game immediately. To create a simulation the trainer simply uploads to the tool the XML file with the description of the game design in which the simulation will be based. The tool sends the file to the GRE Platform, which processes it and generates the virtual environment for the game to be played. The standard game view is then extended to show the authoring tool interface, which is composed of a set of semi-transparent windows that allow visualizing the game scene while defining the simulation. Using this interface and the standard game controls the trainer can:

Set up the initial conditions of the simulation: New instances of the game entities can be easily added just by dragging and dropping their names from the list of game entities (top left hand side of the screen) to the position of the scene in which the trainer wants then to be placed. The graphical model of the entity will be added, and a pop up screen will be displayed to allow introducing the values for its attributes (Figure 1). The window on the bottom left hand side shows the list of instances of the entities currently defined.

Define the events of the simulation: The list of events currently included in the game design is depicted in the bottom right hand side of the screen. To configure the events of the simulation the trainer can modify the existing game events, or define his or her own. In the latter case it will be necessary to choose the type of event to add, and to fill out a form displayed in a pop up window with the information about its triggering condition and their outcomes.

Test the simulation: At any given moment the trainer can take control of the game entities, changing their positions and triggering their actions. This allows rapid checking of whether the events defined are activated according to what it is expected and, therefore, if the simulation is correctly defined.

Figure 1. Screenshot of the GRE Simulations Authoring Tool

Export: Once the simulation has been tested the final design can be exported as a game design XML file, which can be uploaded and played in the GRE Platform.

Use Case: A Rescue and Fire Extinction Simulation Game

As a preliminary evaluation of the presented approach we designed and developed a 3D virtual environment for supporting training in rescue and fire extinction operations. On the one hand, we designed a game in which the player should rescue people from a fire while trying to extinguish it without harm from the fire and smoke. On the other hand we designed a simulation to support the analysis of the possible impact of toxic or inflammable materials or strong wind on the operational procedures (Figure 2). These source events could impact on the probability of occurrence of the dynamic and/or outcome events.

Figure 2. – Set of events considered in the simulation "Rescue and Fire Extinction Operation"

Once all the interrelated probabilities of the events were estimated, we proceed to load the information for the simulation in the game using the GRE Simulation Authoring Tool. For example, to represent the possibility of flammable and toxic materials (source events) two random game events were set up that, when triggered, decrease the activation thresholds of the random events that represent the dynamic events "large scale fire" and "toxic smoke", respectively. In case these events are also triggered the values of the attributes "speed propagation" of the game entity "fire", and "damage" of the game entity "smoke" will be increased. The player should respond to the occurrence of these events in real time, while searching for the location of the outbreak of the fire and the position of the victims, extinguishing the fire, etc. At the end of the play the monitor service generates a report based on the level of injuries of the victims and the rescue and fire extinction personal, the level of the material damages and the extinction of the fire (Figure 3).

CONCLUSIONS AND FUTURE WORK

The importance of simulation exercises lies in their ability to clarify the exact responsibilities of each participant's role and improve his/her performance in carrying out each task. In this paper we present a pioneer combination of 3D virtual environments and cross-impact principles that is aimed at representing complex emergency situations, including both quantitative and qualitative information and supporting real-time simulations in order to improve current virtual training environments. Moreover, the simulation exercises might be used as an evaluation of the plan, insofar as they can help in identifying weaknesses or possible improvements in policies and procedures. So our future research will be focused on sharing scenarios for planning and training in order to see how to test and improve plans by assessing them in training sessions supported by virtual environments. In addition, a new version of the GRE Platform for multiplayer EGs is under development, which will provide support for team training and other features such as us changing tasks and difficulties attending to the initial requirements.

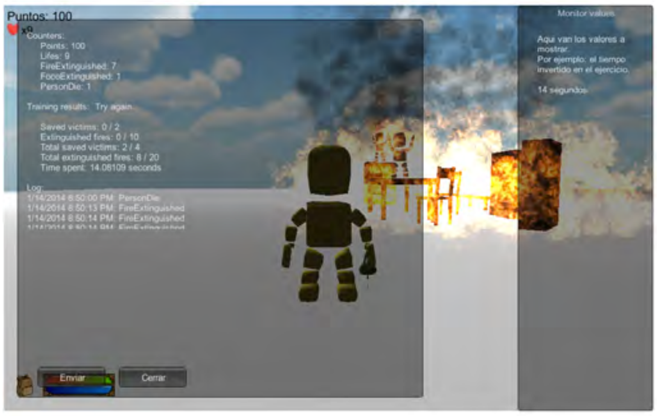

Figure 3. Screenshot of the "Rescue and Fire Extinction Operation" simulation

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