An Immersive Virtual Reality Training Simulation for Risk Management

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Abstract. The satisfactory management of risk situations involves risk identification, the development of risk handling strategies and plans and the conduct and monitoring of those plans. There are a number of examples of (text-and desktop-virtual reality based) Risk Assessment systems providing a list of risk assessment measurements for contingency plan development and a matrix for risk-based scenario development. We developed a virtual reality training system, BOSS (BOrder Security Simulation) for training airport customs officers, using an immersive semi-cylindrical projection system (VISOR: Virtual and Interactive Simulation of Reality) in our Virtual Reality Systems (VRS) Lab to test the level of immersion. The system consists of three projectors which display the virtual world onto a 6m wide semi-cylindrical screen canvas. The user is positioned slightly off centre towards the canvas to allow a 160° field of view (FOV). We use Vizard Virtual Reality Software and datagloves to interact with non-player characters (NPC), developing a gesture and speech based interface. Our purpose is to test the effects of immersion on the quality of learning and to determine what factors are most important and pertinent to learning in an immersive virtual environment. The factors we intend to test through controlled experimental studies include: Peripheral vision, Screen size, Stereoscopic vision, Lighting cues (more for depth perception than just immersion), Sound (mono / stereo / surround sound), Ambient Sound, Interface (keyboard mouse / data gloves / voice). We will measure the effects of these factors in engagement and learning using a number of bio feedback devices (EEG, ECG, EGG, etc.) BOSS offers a prototype platform for building, integrating and testing for further developing our ideas and other related research. In this paper, we describe the system architecture of BOSS using HLA standard.

1. INTRODUCTION

1.1 Risk Management

The satisfactory management of risk situations [5] involves risk identification, the development of risk handling strategies and plans [10][13] and the conduct and monitoring of those plans. As an example of a text-based Risk Assessment system, Decker [5] provided a list of risk assessment measurements for contingency plan development and a matrix for risk-based scenario development. Kavakli and Gao [9] developed a “Virtual Crime Prevention through Environmental Design Kit” (Virtual CPTED). The Virtual CPTED kit enables trained and experienced police officers to identify and quantify the crime risk, situational hazards and social conditions that are believed to attract and/or facilitate criminal behaviour. Furtado and Vasconselos [7] developed ExpertCop, a desktop VR training simulation for police officers who configure and allocate an available police force for a selected urban region and then interact with the simulation. The goal of the training in ExpertCop is to induce members of the police force to reflect on resource allocation to prevent crime. The training simulator receives a police resource allocation plan as input, and it generates simulation scenarios of how the crime rate would behave in a certain period of time. Although both Virtual CPTED and ExpertCop stressed the importance of interaction for the quality of learning, none of them addressed the effects of immersion in training simulations for risk management.

Risk management affects decision making in areas as diverse as the environment and engineering [2] In the well-known spiral life-cycle model [3], risks are the key driver behind the choices made at each phase and iteration of system development. To assist with the project management related risks, Niwa [16] incorporated knowledge base systems (KBS) technology as it provides a way of structuring the dependencies between the different variables required for decision making. Using situation analysis Yang et al. [24] has developed a KBS for assessing and managing the risk associated with bank loans. Also in the financial sector, KBS have been used for the modelling of financial decision problems regarding the assessment of corporate performance and viability [25].

Relevant to risk assessment is the notion of information assurance. For example, when dealing with organisational espionage and military risk situations, knowing the level of accuracy and reliability of the information you have received is difficult but essential. Again, KBS can be used to check the consistency and completeness of the information received. Another approach is development of a Network Intrusion Detection Systems (IDS) incorporating a KBS to ensure network data has not been tampered with [20]. Evidence of the growing emphasis on managing authorised access to knowledge are forums such as the recent “Second Secure Knowledge Management Workshop (SKM) 2006”.

More recently, multi-agent systems in which autonomous agents capable of independent reasoning and action work together using individual and/or common knowledge bases are being used to perform decision making. For example, Lorenz et al. [12], have combined “risk management, knowledge management, and agent deliberation to enable distributed and autonomous decision-making”. Each agent manages it own fraction of the knowledge base containing the knowledge needed by the entire system for risk management. Kavakli et al. [8] also demonstrated a multi-agent based approach to the development of a training simulation for risk management.

1.2 Immersion in Training simulations

Prior to a detailed discussion on war simulations and games, it is beneficial to clarify the definitions of the concepts we will use in this chapter. The terminology described by the U.S. Department of Defense [22] - regarding war simulations and games - is as follows: [19] ***Simulation*** is a method for implementing a model over time. War Game is a simulation in which players try to achieve a military objective. Military training simulations can be classified into three groups [4][17] virtual, constructive, and live simulations. In virtual training simulations, the user is immersed in a virtual world. In constructive simulations, tactical and strategic decisions are made testing the user’s ability to use their forces effectively. Live simulations allow users to practice the physical activities of war with their real equipment.

Before World War II, Edward Link developed the first pilot training simulator called The Blue Box [17][11] Link’s training simulation “Link Trainer” helped prepare more than half a million aircrew members during the war and afterwards. In 1979, The Department of Defense funded improvements in the area of computer graphics and one result of this was the development of the geometry engine [17]. In the early 1980's microcomputers became available to the public on a large scale, this in turn gave computer games a widespread appeal, such as Eastern Front (a simulation of the German - Russian conflict in World War 2), and “Battlezone” (the Atari tank battle game to enhance the hand-eye coordination of armour crews) [11]. In 1993 the commercial version of the three-dimensional first person shooter game “Doom” was released and the US Marines edited the commercial version of “Doom” to create “Marine Doom”. In addition to Doom, Falcon 4.0, Flight Simulator, Hargoon 2, Tigers on the Prowl, Operation Crusader, and Patriot were all used for military training [17]

Around 1988 the military began to explore the possibility of linking multiple interactive training simulations. In 1988 the Defense Advanced Research Projects Agency (DARPA) initiated a program called Simulator Networking (SIMNET) to create multiple tank simulators that could be joined over a network such that each could detect, engage, and destroy the others [15]. This program resulted in the establishment of important principles for simulation interaction and the creation of a network messaging protocol to exchange essential data. SIMNET was the forerunner of the Distributed Interactive Simulation (DIS) protocols. DIS attempted to generalize the SIMNET technology so that it could be applied to a wider variety of combat vehicle simulators such as trucks, helicopters, fighters, ships, and soldiers. The Distributed Wargaming System fielded at the German ACE-89 exercise demonstrated the feasibility of tracking military units in other simulations and engaging them effectively and accurately. This experiment led to the development of the Aggregate Level Simulation Protocol (ALSP) to demonstrate interoperable training at the staff level [23].

The role of simulation technology began moving from the training community into the operational test area. This complex test activity involving controlled computer simulations of battle environments and conditions is known within the Army as the Virtual Proving Ground (VPG). It is not a single place but a network of test centres. As a result of the development in the simulation technology, the U.S. Army attempts to build the seamless virtual proving ground of the future. Creating a totally integrated test environment requires integration of architecture, synthetic environments, information systems and tools. The implementation of a High Level Architecture (HLA) (DMSO 1997) is of major importance to the future coordinated test world, and vital to software reuse, to seamless integration and to interoperability [14].

The Mission Rehearsal Exercise System (MRE) [21] was supported by the US Army in order to develop an immersive learning environment where the participants experience the sights, sounds, and circumstances, as they encounter real-world scenarios. Its aim is to build intelligent agents that are able to respond and adapt to their environment in natural and believable ways, creating a movie-like realism. Commercial simulation environments that are currently available offer minimal user interaction, cannot be used to define complex training scenarios, and use scripted characters that cannot react appropriately to the user or the events.

The Army’s Soldier Systems Center, in Natick, Massachusetts, has decided to use immersive Virtual Reality (VR) systems in training and commissioned the games developer Novalogic California, to modify the popular Delta Force 2 game to help familiarize soldiers with the service’s experimental Land Warrior system [11]. The Land Warrior system includes a self-contained computer and radio unit, a global-positioning receiver, a helmet-mounted liquid-crystal display and a modular weapons array that adds thermal and video sights and laser ranging to the standard M-4 carbine and M-16A2 rifle. A customized version of another computer game, Microsoft Flight Simulator, is issued to all U.S. Navy student pilots and undergraduates enrolled in Naval Reserve Officer Training Courses at 65 colleges around the U.S.A. [17].

More recently, the immersive VR systems have been widely adopted by the military worldwide. Visualization specialist Barco delivers a second fivechannel high-resolution mini-dome simulator (the SEER mini-domes, with a radius of 1.5 m). The SEER mini-domes are relocatable and provide full immersion with constant eye relief over the entirely spherical surface to enable effective training of fast jet pilots using Typhoon Emulated Deployable Cockpit Trainer (EDCT) in the RAF's 29 Squadron Operational Conversion Unit (OCU) [1]. The EDCT, procured as part of the Eurofighter Aircrew Synthetic Training Aids (ASTA) programme, was conceived as a low-cost deployable device to enable pilots to practise and maintain currency whilst on operational deployment. The system was engineered using SimCAD design software to optimize projector placement to best cover a Horizontal Field Of View of 220 degrees (-110: +110) and a Vertical Field Of View of 140 degrees (–50: +90) while negating distracting shadows from the cockpit structure [1].

2. ENGINEERING A VIRTUAL REALITY SIMULATION

We developed a virtual reality training system, BOSS (BOrder Security Simulation) for training airport customs officers, using an immersive semi-cylindrical projection system (VISOR: Virtual and Interactive Simulation of Reality) in our Virtual Reality Systems (VRS) Lab to test the level of immersion. The system consists of three projectors which display the virtual world onto a 6m wide semi-cylindrical screen canvas. The user is positioned slightly off centre towards the canvas to allow a 160° field of view (FOV) as shown in Figure 1.

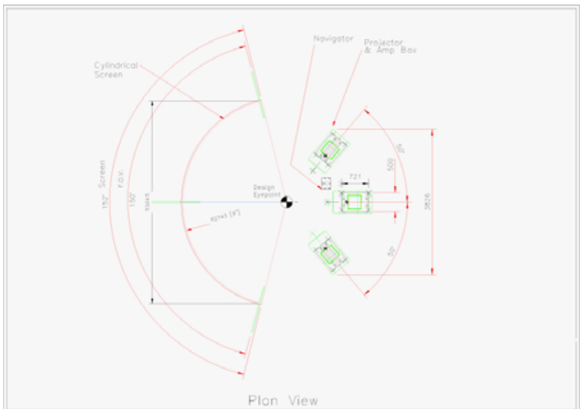

Figure 1: Plan view of VISOR

We used Vizard Virtual Reality Software and a pair of datagloves to interact with the non-player characters (NPCs), developing a gesture based interface. Our primary goal is to determine what factors are most important and pertinent to learning in an immersive virtual environment. The factors we intend to test through controlled experimental studies include: Peripheral vision, Screen size, Stereoscopic vision, Depth cues (such as lighting), Sound (mono / stereo / surround sound), Ambient Sound, Interface (keyboard mouse / data gloves / voice).

Figure 2: Perspective view of the VISOR installation

We used Softimage|XSI for creating a 3D landscape and an airport model. We modified the layout of the digital world in Blender. We exported the digital world to Vizard file format. We used 3D Studio Max and Softimage|XSI with FBX plug-ins for 3D modelling. 3D Studio Max has a built in exporter for .FBX format which MotionBuilder reads. In MotionBuilder, we set up the rig of the character and applied the Motion-Capture (mocap) animation onto the character's skeleton, see Figure 3. The animation footage is produced by Vizard Virtual Reality software.

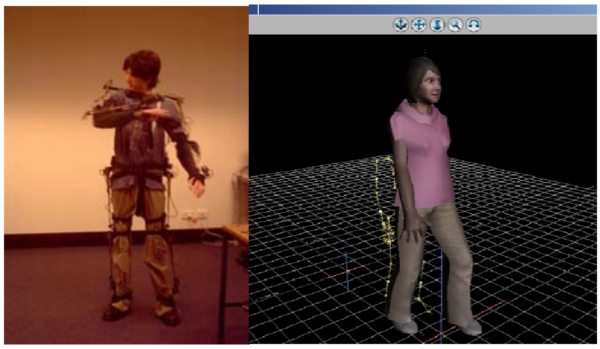

Figure 3: 3D character animation driven by mocap data

3. SYSTEM ARCHITECTURE OF A TRAINING SIMULATION FOR RISK MANAGEMENT

For interoperability, extendibility, maintenance and reusability purposes we have taken a modular design approach where each component has separate roles and responsibilities and well defined interfaces to allow other components to access their functionality. Also driving our modular design is the desire to (re)use existing third party components and swap components as required. For example, a Story Engine (top right) has been integrated to the system using socket connection [8] and a Behaviour Engine coded in Java, but may be replaced by other story development techniques. The system architecture is shown in Figure 4.

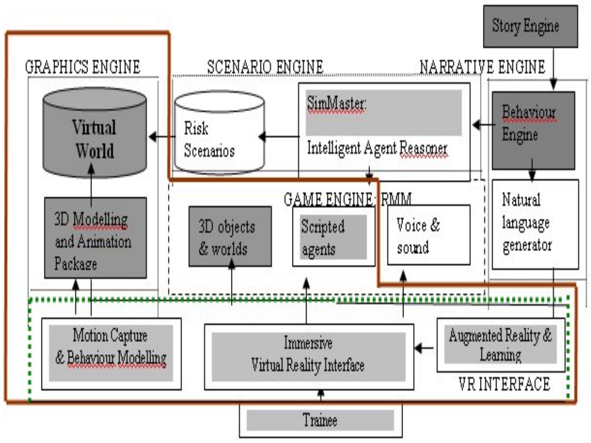

Figure 4: BOSS System Architecture

Many of the components are provided by third party vendors such as the 3D Modelling and Animation Package (Softimage and 3D Max) and Virtual Reality Software (Vizard) and speech synthesiser (Festival).

In the first implementation of our system, which began in 2005, the Unreal Tournament (UT2004) game engine was used to provide the components marked as "3D objects and worlds, scripted agents and voice and sound". A modification, in the form of a plugin to UT2004, known as the Risk Management Mod (RMM), was created which acts very similarly to the GameBots modification that began at the University of Southern California's Information Sciences Institute for research in AI. The Behaviour Engine (BE) is a module transforming high level actions calculated by the Story Engine (SE) into low level animation commands for the Unreal Tournament Game Engine. The natural language generator is currently under development and when complete will allow generation of paraphrased sentences according to the given context which will be passed to it. The Narrative Engine and the Sim Master are external client programs where the decisions related to the action of the non-player characters (NPC)s such as walk, run, turn and talk can be controlled. The SimMaster module is simply an interface which allows a human to send and receive messages from the system. We developed a multi-agent system known as RiskMan [8] Currently a VR prototype, known as BOSS, is being developed to extend and replace the RMM with the set of enclosed modules in Figure 4

4. SIMULATION VERIFICATION

As part of our redevelopment and extension of the original RMM system, we are redesigning each module to conform to the High Level Architecture (HLA) standard in BOSS. We describe the redesign process as follows:

Step 1 involves evaluation of our current and proposed simulation in the context of reuse and interoperability. To support reuse we considered the modularity of our current system. We found the design to be in accordance with the design concepts of low coupling and high cohesion, where each module focuses on a particular aspect of the system and has minimal dependencies with other modules. We identified the purpose of our simulation to be training involving the rehearsal of questions and situations the trainee was likely to encounter. The fidelity of the simulation was enabled through the use of actual scenarios experienced by experienced customs officers. While the potential application is initially customs officers, the training simulation could also be applied to other interview or interrogation type situations. We believe most of the technology being developed is applicable beyond question/answering situations such as quests or mission rehearsal exercises where the participant is required to make choices at certain times between options/paths provided or make decisions about what they should say or do.

Step 2 requires development of a simulation object model (SOM). As recommended by the standard, we sought to reuse existing simulation objects from the United States Defense Modelling and Simulation Office (DMSO) Object Model Resource Center (OMCR). However, we were unable to gain access to these without a US Government sponsor. Thus we have created the following object model for the customs officer domain we are working with, keeping in mind reusability of the system for other domains.

The key objects within our domain include: passengers, trainee customs officers, supervisor trainee officers, furniture, travelgoods, rooms and items as shown by the entity classes in the class diagram in Figure 5, which is drawn in BlueJ a Java development environment. Some of these objects, such as rooms, have limited behaviour. In the real world objects such as furniture, luggage and items also have limited behaviour, but in an object oriented sense we can ask a desk to move itself, a suitcase to open or close itself, or an item to pick itself up or be examined. We have thus allowed such behaviours for our objects. The behaviour of inanimate objects will be controlled by animate objects, that is the people in the scenarios, who will tell the objects when to perform the behaviours they are capable of. We also have animate objects, such as some passenger or person objects who will similarly be controlled (or scripted) to perform certain actions by the system or other animate objects.

We have created a number of generalization-specialisation hierarchies to allow inheritance of structure and behaviour of superclasses, also known as base or parent classes. For example the person class is the base class for the passenger and customs officer classes. The Trainee and Supervisor classes further extend the Customs Officer class. Also as shown in Figure 5, we have created a Furniture and a TravelGoods superclass. We anticipate needing to create a number of other classes to represent objects which may be examined such as passports or extracted from luggage such as food items, clothing and toiletries. However, the current simulation is not planned to have this level of detail or sophistication. To allow for these future extensions we have created an overall class called Items which can be inspected. The arrows between the superclasses indicate the relationships and dependencies between the classes. For example a Person may be in a certain Room, a Person may own or inspect certain Items or TravelGoods, TravelGoods may be placed on top of a certain Furniture object and that Furniture may be located in a Room.

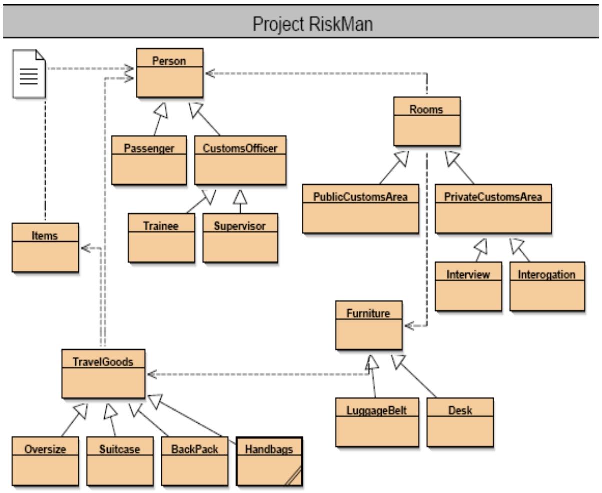

Figure 5: Figure 5: Entity Class Diagram showing the high level Simulation Object Model for the Customs Officer Training Simulation.

The entity class model presented will be used as a template for each module that we develop and the attributes and behaviours which define those objects will depend on the nature of the module. For example, the 3D objects and worlds will contain objects of the above classes. These will form the Customs Officer World, which is a subset of the Airport World. Some of these objects may be reused in other, yet to be defined, Worlds such as a Hotel World will contain rooms and furniture and people. However we would need to add new subclasses to Rooms such as Suite, Single, Double, Queen, Ensuite and/or Restaurant and Bed, Dressing Table and Wardrobe as subclasses of Furniture.

For the Voice and Sound module we will describe attributes and/or behaviours relevant to these classes regarding speech. For example, attributes such an intonation, emotion, accent, gender and age will be applicable to all Person objects. According to the values of these attributes different utterances will be generated and behaviours invoked. We are also able to add sounds to TravelGoods such as the sound of a zipper when a BackPack is being opened, or the slam of a Suitcase when it is shut. Rooms will be able to have their own sounds. Placing or movement of items or Travel Goods on certain Furniture will also have its specialized sounds. For each component to be developed the class diagram will provide a basis for structuring the functionality of the module. The complete description of each class including the attributes, parameters or data types are not provided here for space and relevance reasons but are stored in a lexicon for easy lookup and reuse by the system designers.

Step 3 of the HLA standard requires identification of the Run-Time Infra-structure (RTI) Services required to support the SOM. Currently our project is a standalone one that we intend to develop as a proof of concept to the national protection and defense industry. Thus at this stage our simulation is not part of a federation wide activity but the steps involving federation, declaration, object, ownership, time and data distribution management would need to be specified and integrated should our simulation form part of a wider simulation exercise.

We have commenced the implementation phase (step 4) involving integration with third party APIs, use of CASE tools and development of our own components and their respective interfaces and data handling and storage. Verification and validation are critical parts of each of the system development phases ranging from requirements specification verification using structured walkthroughs and validation against real scenarios down to unit, system and integration testing of each module. Documentation as part of Step 5 is being performed and updated throughout. Submission of our SOM is not relevant or possible as we are not an MSRR member. Planning of future versions is an activity that we continue to discuss and revise as our project is primarily research rather than development. Some future plans are considered next.

5. FUTURE PLANS

Using computer games for training relies first of all on the assumption that people are able to learn from a game, in particular, that they do not find an animation distracting or in some way inappropriate for training. In an initial study conducted in 2005 involving 74 third year computer graphics students, we compared the accuracy of answers to watching a training video to watching a game demonstration of the same content. We found that participants perception, memory and reasoning were not significantly different using different forms of media (video versus game demo). A key outcome of that study [18] was that the participants believed that interactivity was critical for using the game environment successfully for learning.

In the future stages of this project, our purpose is to test the effects of immersion on the quality of learning in training simulations and to determine what factors are most important and pertinent to learning in an immersive virtual environment. The factors we intend to test through controlled experimental studies include: Peripheral vision, Screen size, Stereoscopic vision, Lighting cues (more for depth perception than just immersion), Sound (mono / stereo / surround sound), Ambient Sound, Interface (keyboard mouse / data gloves / voice). We will measure the effects of these factors in engagement and learning using a number of bio feedback devices (EEG, ECG, EGG, etc.) Our system combines our research into speech; emotion and gesture recognition; cognitive and behavioural modelling; incremental knowledge acquisition; agent systems; game technology; narrative engines and adaptive and intelligent user interfaces. BOSS offers a prototype platform for building, integrating and testing for further developing our ideas and other related research.

Acknowledgment

This project is sponsored by the Australian Research Council (ARC): ARC Discovery Grant (DP0558852 titled Risk Management Using Agent Based Virtual Environments). Special thanks to Iwan Kartiko for supporting this project in the production of 3D models and digital animations.

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