Emerging Applications in Immersive Technologies

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INTRODUCTION

The world of Virtual Environments and Immersive Technologies (Sutherland, 1965) (Kalawsky, 1993) are evolving quite rapidly. As the range and complexity of applications increases, so does the requirement for intelligent interaction. The now relatively simple environments of the OZ project (Bates, Loyall & Reilly, 1992) have been superseded by Virtual Theatres (Doyle & Hayes-Roth, 1997) (Giannachi, 2004), Tactical Combat Air (Jones, Tambe, Laird & Rosenbloom, 1993) training prototypes and Air Flight Control Simulators (Wangermann & Stengel, 1998).

This article presents a brief summary of present and future technologies and emerging applications that require the use of AI expertise in the area of immersive technologies and virtual environments. The applications are placed within a context of prior research projects.

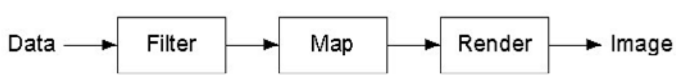
BACKGROUND

Visualisation is defined as the use of computer-based, interactive visual representations of data to amplify cognition. The much cited process driven visualisation pipeline proposed by Upson et al (1989) is shown in Figure 1. Upson and his colleagues define three processes consisting of filtering, mapping and rendering the data. The image presented allows the user to draw some inference and gain insight into the data.

The *Filter* process is when data of interest are derived from the raw input data; for example, an interpolation of scattered data onto a regular grid. This data is then *Mapped* into geometric primitives that can be then be *Rendered* and displayed as an image to the user. The user may then gain an improved understanding and greater insight into the original raw data. The type of data and application area heavily influence the nature of the mapping process. That is, choosing the actual visualisation technique that we are going to use. For example, if the data consisted of 1D scalar data, then a simple line graph can be used to represent the data. If the filtered data consists of 3D scalar data, then some form of 3D isosurfaces or direct volume rendering technique would be more appropriate. Through the various specifications and conceptualisations of the filter-map pipeline above, we would propose an ontology that describes the relationships between data type and mapping processes that facilitates the automatic selection of visualisation techniques based on the raw data type. As the applications become more sophisticated the visualisation process can make use of the data ontology to drive AI controlled characters and agents appropriate for the application and data.

A starting place for this can be seen in the area of believable agents (Bates, Loyall & Reilly, 1992) where the research ranges from animation issues to models of emotion and cognition, annotated environments. Innovative learning environments and Animated Pedagogical Agents (Johnson, Rickel & Lester, 2000) provide further areas for development, as do industrial

Figure 1. Upson et al's visualisation pipeline



applications, for example Computer Numerical Control (CNC) milling operations virtual training prototype system (Lina, Yeb, Duffy & Suc, 2002). Teaching environments using multiple interface devices in virtual reality include Steve (Soar Training Expert for Virtual Environments) that supports the learning process (Rickel & Johnson, 1999) with collaborators including Lockheed Martin AI Center. SOAR (Laird, Hucka & Huffman, 1991) has also been used for training simulation in air combat (TacAir-Soar) (Jones, Tambe, Laird & Rosenbloom, 1993). This autonomous system for modelling the tactical air domain brings together areas of AI research covering cognitive architectures Human Behavior Representation (HBR) / Computer Generated Forces (CGF). SOF-Soar: (Special Operations Forces Modeling) (Tambe, Johnson, Jones, Koss, Laird, Rosenbloom and Schwamb, 1995) uses the same underlying framework and methods for behavior generation based on the Soar model of human cognition, each entity is capable of autonomous, goal-directed decision-making, planning, and reactive, real-time behavior. As the world of digital media expands emerging applications will draw on the worlds of Virtual Theatres (Giannachi, 2004), interactive storyline games and others forms of entertainment (Wardrip-Fruin & Harrigan, 2004) to enhance the visualisation experience, especially where virtual worlds involving human artifacts and past and current civilisations are involved.

SWARM INTELLIGENCE FOR VISUALISATION

Understanding the behaviour of biological agents in their natural environment is of great importance to ethologists and biologists. Where these creatures move in large numbers is a challenge for orthodox visualisation.

Working with marine biologists, a 3D model of large numbers of swarming krill (Figure 2) has been created. The model augments the classic swarming functions of separation, alignment and cohesion outlined by Reynolds (1987). The generated 3D model allows cameras to be placed on individual krill in order to generate an in-swarm perspective. New research on Antarctic krill (Tarling & Johnson, 2006) reveals that they absorb and transfer more carbon from the Earth's surface than was previously understood. Scientists from the British Antarctic Survey (BAS) and Scarborough Centre of Coastal Studies at the University of Hull discovered that rather than doing so once per 24 hours, Antarctic krill 'parachute' from the ocean surface to deeper layers several times during the night. In the process they inject more carbon into the deep sea when they excrete their waste than had previously been understood. Our objective has been to provide marine biologists with a visualisation and statistical tool that permits them to change a number of parameters within the krill marine environment and examine the effects of those changes over time. The software can also be used as a teaching tool for the classroom at varying academic levels.

Figure 2. 3D krill and sample 3D swarm

The marine biologist may modify parameters relating to an individual krill's field of view, foraging speed, collision avoidance, exhaustion speed, desire for food etc. The researcher may also modify more global parameters relating to sea currents, temperature and quantity and density of algae (food) etc.

Upon execution, the biologist may interact with the model by changing the 3D viewpoint and modifying the time-step which controls the run speed of the model. Krill states are represented using different colours. For example, a red krill represents a starved unhealthy krill, green means active and healthy, blue represents a digestion period where krill activity is at a minimal. Recent advances in processor and graphics technology means that these sorts of simulations are possible using high specification desktop computers. Marine biologists have been very interested in seeing how making minor changes to certain variables, such as field of view for krill, can have major consequences to the flocking behaviour over time of the entire swarm.

Figure 3. VR paragliding simulator

PARAGLIDING SIMULATOR

The Department of Computer Science at the University of Hull have recently developed the world's first ever paragliding simulator (SimVis, 2007). The system provides a paragliding pilot with a virtual reality immersive flying experience (Figure 3). As far as the user is concerned, they are flying a real paraglider. They sit in a real harness and all physical user inputs are the same as real life. Visuals are controlled via a computer and displayed to the user via a head-tracked helmet mounted display. The simulator accurately models winds (including thermals and updrafts), photorealistic terrain and other computer controlled AI pilots.

Figure 4 shows a typical view from the paragliding simulator. To the right of the image, the user can see four paragliding pilots circling a thermal. It is in the user's interests to fly to this region to share in the uplift, gaining altitude and therefore flight time.

This prototype is being developed along the lines of SOF-Soar: (Special Operations Forces Modeling) (Tambe, Johnson, Jones, Koss, Laird, Rosenbloom and Schwamb, 1995). It requires an expert tutoring system encompassing the knowledge of expert pilots. Like some virtual learning environments it needs to build a trainee profile from a default and adapt to the needs of the novice flyer. For example the system can create an AI Pilot flying directly at the user forcing the user to practise collision avoidance rules. If pilots collide in the simulator, both pilots will become wrapped in each others canopies and they will plummet down to the earth and die. As virtual fly-time accumulates the system needs to adapt to the changing profile of the user. An expert system could be used to force the user to make certain flight manoeuvres that test the user's knowledge of CAA air laws. For example, the AI system may decide that the user is an advanced pilot due to their excellent use of thermal updrafts etc. The system therefore works out how to put our pilot into a compromising situation that would test their skills and ability such as plotting a collision course with our pilot when they are flying alongside a cliff edge. If our pilot is a novice, then the system would present simpler challenges such as basic collision avoidance. This is an advanced knowledge engineering project that blends traditional AI areas such as knowledge engineering with more nouvelle fields such as agent based reactive and cognitive architectures and state of the art visualisation and immersive technologies.

Figure 4. Real-time pilot's view from the paragliding simulator including other AI controlled pilots

CONCLUSION

This article suggests that cognitive science and artificial intelligence have a major role to play in emerging interface devices that require believable agents. As virtual environments and immersive technologies become ever more sophisticated, the capabilities of the interacting components will need to become smarter, making use of artificial-life, artificial intelligence and cognitive science. This will include the simulation of human behaviour in interactive worlds whether in the modelling of the way data and information is manipulated or in the use of hardware devices (such as the paraglider) within a virtual environment.

REFERENCES

Bates, J., Loyall, A.B. & Reilly, W.S. (1992). An Architecture for Action, Emotion, and Social Behavior. Tech. Report CMU-CS-92-142, School of Computer Science, Carnegie Mellon University, Pittsburgh.

Doyle, P. & Hayes-Roth, B. (1997). Guided exploration of virtual worlds. In Network and Netplay: Virtual Groups on the Internet. F. Sudweeks, Ed. MIT Press: Cambridge, MA.

Giannachi, G. (2004). Virtual Theatres: An Introduction. London: Routledge Press.

Hayes-Roth, B., Brownston, L. & van Gent, R. (1995). Multiagent collaboration in directed improvisation. Proc. 1st Int. Conf. on Multi-Agent Systems, San Francisco; Reprinted in Readings in Agents, M. Huhns and M. Singh, Eds. Morgan-Kaufmann: San Francisco.

Johnson, W.L, Rickel, J.W. & Lester, J.C. (2000). Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments. International Journal of Artificial Intelligence in Education 11, 47-78.

Jones, R. Tambe, M., Laird, J. & Rosenbloom, P. (1993). Intelligent automated agents for flight training simulators. Proceedings of the Third Conference on Computer Generated Forces and Behavioral Representation. University of Central Florida. IST-TR-93-07.

Kalawsky, R. S. (1993). The Science of Virtual Reality and Virtual Environments: A Technical, Scientific and Engineering Reference on Virtual Environments. Addison-Wesley, Wokingham, England ; Reading, Mass.

Laird, J., Hucka, M. & Huffman, S. (1991). An analysis of Soar as an integrated architecture. SIGART Bulletin, 2, 85-90.

Lina, F., Yeb, L., Duffy, V.G. and Suc, C.-J. (2002). Developing virtual environments for industrial training. Information Sciences, 140(1-2), 153-170.

Reynolds, C. W. (1987). Flocks, Herds, and Schools: A Distributed Behavioral Model. Computer Graphics, 21(4), 25-34.

Rickel, J. & Johnson, W.L. (1999). Animated Agents for Procedural Training in Virtual Reality: Perception, Cognition, and Motor Control. Applied Artificial Intelligence, 13, 343-382.

SimVis (2007) Virtual Paragliding Project, SimVis Research Group. Web: www.dcs.hull.ac.uk/simvis/projects/paraglider

Sutherland, I. E. (1965). The Ultimate Display. Proceedings of IFIP 65, (2), 506-508

Tambe, M., Johnson, W. L., Jones, R. M., Koss, F., Laird, J. E., Rosenbloom, P. S. & Schwamb, K. (1995). Intelligent Agents for Interactive Simulation Environments. AI Magazine, 16(1).

Tarling, G. & Johnson, M. (1996). Satiation gives krill that sinking feeling. Current Biology, 16(3), 83-84.

Upson, C., Jr, T. F., Kamins, D., Laidlaw, D., Schlegel, D., Vroom, J., Gurwitz, R. & van Dam, A. (1989). The Application Visualisation System: A Computational Environment for Scientific Visualisation. IEEE Computer Graphics and Applications 9(4), 30-42.

Wangermann, J.P. & R. F. Stengel, R.F. (1998). Principled Negotiation Between Intelligent Agents: A Model for Air Traffic Management. Artificial Intelligence in Engineering, 12(3), 177-187.

Wardrip-Fruin, N. & Harrigan, P. (Eds.) (2004). First Person: New Media as Story, Performance, and Game. MIT Press.

KEY TERMS

Air Flight Control: A service provided by ground-based controllers who direct aircraft on the ground and in the air. A controller's primary task is to separate certain aircraft — to prevent them from coming too close to each other by use of lateral, vertical and longitudinal separation. Secondary tasks include ensuring orderly and expeditious flow of traffic and providing information to pilots, such as weather, navigation information and NOTAMs (Notices to Airmen)

Flocking: A computer model of coordinated animal motion such as bird flocks and fish schools. Typically based on three dimensional computational geometry of the sort normally used in computer animation or computer aided design.

Knowledge Engineering: Knowledge engineering is a field within artificial intelligence that develops knowledge-based systems. Such systems are computer programs that contain large amounts of knowledge, rules and reasoning mechanisms to provide solutions to real-world problems. A major form of knowledge-based system is an expert system, one designed to emulate the reasoning processes of an expert practitioner (i.e. one having performed in a professional role for very many years).

Virtual and Immersive Environments: Virtual environments coupled with immersive technologies provide the sensory experience of being in a computer generated, simulated space. They have potential uses in applications ranging from education and training to design and prototyping.

Virtual Theatres: The concept of "Virtual Theatre" is vague and there seems to be no commonly accepted definition of the term. It can be defined as a virtual world inhabited by autonomous agents that are acting and interacting in an independent way. These agents may follow a predetermined manuscript, or act completely on their own initiative.