

Virtual Agents in a Simulated Virtual Training Environment

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ABSTRACT

A drawback to live-action training simulations is the need to gather a large group of participants in order to train a few individuals. One solution to this difficulty is the use of computer-controlled agents in a virtual training environment. This allows a human participant to be replaced by a virtual, or simulated, agent when only limited responses are needed. Each agent possesses a specified set of behaviors and is capable of limited autonomous action in response to its environment or the direction of a human trainee. The paper describes these agents in the context of a simulated hostage rescue training session, involving two human rescuers assisted by three virtual (computer-controlled) agents and opposed by three other virtual agents.

1 INTRODUCTION

Virtual training environments are gaining in popularity because of many attractive features, some of which are increased safety, reduced training cost, and simulated scenarios that would be impossible to duplicate in live-action training. However, once one uses a computer to create the training environment, it is possible to take a further step and simulate some of the participants in the exercise who are present in only a supporting role. This is presently done at the level of vehicular entities, such as airplanes and tanks, in battlefield simulations. The replacement of human participants with simulated agents is possible when the responses required of the agent are well-defined and only limited autonomous action is needed. Not only would the use of simulated agents reduce the number of participants needed for a training session, but it would also afford trainers greater control over elements of the training exercise.

In order to be effective, a simulated agent must be designed with several considerations in mind [5]. These are:

1. **Constructing a reasonable, interactive computer graphics human model**
The model of the agent must not only produce an image that is believable, but the large number of degrees of freedom in a human body must be managed to simplify control. There must be some way to control both local and global positioning.
2. **Incorporating biomechanical correctness**
Since the human body is capable of a wide range of motion, an agent must be able to closely match this range, both in its capabilities and limits. Also, without some notion of what strength can be exerted at different joints, an agent will tend to perform actions that are not considered efficient or natural by human standards.
3. **Developing human-like behaviors**
To simplify control and to produce realistic motions, it is desirable to incorporate a prepackaged set of actions and skills into an agent. [1] Such behaviors would include continuing actions like balance and self-collision avoidance [6], rhythmic motions such as walking [3], and skills such as grasping [6] or sitting.

4. Permitting the agent to perceive and affect the environment

An agent's senses, whether direct like vision or indirect like hearing, must be modeled to account for both the kind of information returned and the limits to their field of detection. An agent must also be able to interact with at least some of the objects in its environment, whether it be to carry something or to open a door.

5. Allowing tasks to be guided by standing commands, instructions, or warnings

In order to be effective, an agent must be able to accomplish some set of programmed instructions, deal with unplanned events, and perform tasks while obeying a list of prohibitions or guidelines. Each of these will govern different elements of how an agent will react in a particular circumstance.

6. Allowing interaction and communication between agents

During a training session, agents may acquire information that will be useful to other agents, or a person in the simulation may wish to issue commands to the simulated agents. To accommodate these situations, there needs to be a mechanism to allow some form of communication between people and agents as well as agents and other agents.

Although virtual agents will vary due to their particular application, there will be common architectural elements to allow them to accomplish these objectives. Though research is continuing, some of these elements can be tested and demonstrated by using them to drive an animation of an prototype agent performing a particular mission. The difficulties encountered in such an animation point to areas needing further refinement and provide a guide for future research.

2 AGENT QUALITIES

As the agent performs its tasks, it will need to respond correctly to the environment, events, and agents around it. Some of these responses will come from modeling physical characteristics, but most will depend on the ways that the agent receives information, decides what tasks to carry out, and uses the skills programmed as basic actions. The qualities needed to achieve these responses include realistic modeling, high-level actions, limited perception and knowledge acquisition, predefined responses and policy, instruction acceptance, and communication.

2.1 Realistic modeling

In order to move and act in a believable manner, a simulated agent must not only incorporate reasonable geometry, but also data on human motion patterns and strength. It may also be necessary, in some cases, to incorporate dynamic simulation to some extent. Whatever the case, there are too many degrees of freedom in a human figure to base motions simply on geometry. Realistic motions tend to minimize the effort exerted by the agent, but even that is not enough to drive a complex activity such as walking [3,4].

2.2 High-level actions

Using high-level action primitives simplifies agent control and provides a more natural way to describe how an agent should behave. As long as actions do not conflict, the agent should be able to perform multiple actions simultaneously and to move smoothly from one action to the next. An example of the first case is simultaneously walking and looking at an object. An example of the second case is walking to a door and then opening it. Especially in the second case, it is important for an agent look ahead in order to behave in a reasonable manner. If it gets too close to the door, for instance, it may not be able to open it. The positioning for the agent will in fact depend on the type of door and the way in which it will be opened, which requires the ability to reason about objects in the environment.

2.3 Limited perception and knowledge acquisition

An agent may begin a simulation with incomplete knowledge about its environment, and its senses may not provide complete information about the area around it. To overcome this, an agent must augment its normal

behavior with actions to acquire more information, position itself to best handle unexpected events, and maintain a system of expectations and assumptions that can be modified as it gains more information. Such a system of assumptions may also dictate what actions an agent will take in order to fill out its picture of the environment. An agent may also have to cope with perceptions that provide only general and indirect knowledge, such as hearing. In this case, some assumptions about the information itself may be required, based on the agent's mission and environment.

2.4 Predefined responses and policy

A simulated agent is not meant to be able to reason its way unassisted through a complex simulation. Instead, it carries out a set of tasks assigned to it at the start or during the simulation. However, there needs to be another set of plans to carry out in case some predefined event occurs, and a set of prohibitions against certain kinds of behaviors or situations. The first kind of plan could be a response to spotting a member of an opposing group, with considerations for the conditions under which the contact was made and what task the agent is trying to accomplish. A prohibition might take the form of a restriction from moving into an unlit area or a rule against executing a particular action when a fellow agent might be injured. In both cases, the prohibition forces the agent to avoid certain actions or at least consider other, preferable alternatives.

2.5 Instruction acceptance

As an agent goes through a simulation, it may receive instructions from a human-controlled agent. The form of the instructions will probably be from a limited, mission-specific vocabulary, from gestures, or by set signals. An agent must be able to interrupt tasks to accomplish others, know how to prioritize tasks when no explicit importance is given, and incorporate the new instruction into its current plan of action. Although the number of instructions may be very limited in a particular simulation, the situations in which they are given can make handling them very complex. [2]

2.6 Communication

As agents acquire information about their environment and accomplish parts of their mission, they may have to relay this information to other simulated or human-controlled agents. While simulated agents could exchange data in a standard format, communication with people could be much more difficult. Probable methods of communication would be through status messages in the person's field of view or even schematics and images for more complicated information that would be difficult to describe without some kind of dialogue that might be beyond the agent's capability.

3 APPLICATION

A reasonable first test of a simulated agent is to try to produce an animation through the use of the qualities described above. One such animation was recently made at the University of Pennsylvania Computer Graphics Research Lab. This animation simulated a training session where three simulated agents were lead by two human-controlled agents to rescue a hostage from three terrorists, all of whom were simulated agents. While the animation showed that the human model and motions worked well in general, it also revealed some problem areas. These included the difficulties involved in managing multiple behaviors simultaneously, recovering from extreme postures such as crouching, and providing an easy way for an agent to manipulate objects in its environment.

Work is also continuing on other elements of the simulated agent architecture. One project, named AnimNL for "Animation from Natural Language", is addressing the issues involved in the higher levels of agent control such as interpreting instructions, working with incomplete knowledge, and reasoning about the objects in the environment. The goal of the project is to construct a complete pipeline to drive an animation from natural language instructions, which will use many of the same techniques that will be needed to direct a simulated agent.

4 CONCLUSION

Although much work remains to be done to achieve the desired agent qualities, significant progress has been made in developing realistic models and producing human motions and behaviors. By addressing the different qualities that will be needed to produce a useful simulated agent, it is possible to break down the elements of the architecture into modules that can be tested and refined. Animation provides a very useful tool for determining the validity of a particular simulated agent architecture by revealing both the quality of the animation as well as the level of animator control needed to produce a correct sequence of actions.

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BIOGRAPHY

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