Pedestrian Behavior Simulation in Real 3D Environments

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Abstract:
Massive virtual models are one of the most computer graphics pieces required on the Internet, especially the ones that simulate three-dimensional urban scenarios. Additionally, the integration of "artificial life" components in these environments, demanding for a virtualization of life involving the static geometry, pioneer in computer games research. This clearly reveals a growing interest for various kinds of analysis in several areas of activity. In this scenario "virtual public facilities" had captured a lot of attention and research efforts when used to simulate and act without certain human constraints that we can find easily in real world. Integrating both Artificial Intelligence (AI) and Computer Graphics (CG) models and strategies it is possible to create effective virtual environments where agents are able to interact with each other and, naturally, with the environment where they are located. This paper presents an integrated model to support agents' behavior when integrated in a three-dimensional urban scenario, describing its basic characteristics and presenting some simulation tests using a great number of agents at different abstraction layers.

Keywords: 3D Animation, Behavior simulation, Computer Graphics, Artificial Intelligence

1. Introduction

The construction of virtual models such as buildings, neighborhoods or cities is, in most of the cases, not oriented to the integration of virtual characters as a form of populating the scenes (with the exception of computer games). Providing "sense of live" in such virtual models, with some levels of autonomy, and associating simulation managed by "desired needs", is a rather arduous task, which involves several scientific areas. Eventual efforts to represent human behavior in a virtual environment usually require the process of real world observation and the consequent systemization of the information that was collected. Artificial Intelligence (AI) must provide a parallel model in the "sensitivity" of some aspects of the virtual environment, creating the basis for decision making processes. So, computer simulations using large crowds, with hundreds or thousands of individuals, require simple and efficient models, but, at the same time, must provide accurate descriptions of reality, as the types of models described in (Schreckenberg, 2002). Most of the systems use a combination of the referred models as a response to a subset of the states occurred in a virtual environment, based on senses, reacting from a combination of answers already planned, or obtained by heuristic methods.

A system that can incorporate and simulate human behaviors, while presenting a realistic and pleasing animation (with quality in real-time rendering) of virtual characters in action, can help end-users to plan conclusions more accurate based on the observation of the virtual world simulation, using them to optimize the sector for which the simulation model was developed.

2. Background

In the vast literature evolving behavior simulation representing individual or group of characters inserted into specific virtual environments, we can distinguish simulations using rule-based methods, global simulation of pedestrians; simulations influenced by physical and social parameters, or even associated with information embedded in the environment. There are a lot of models for such scenarios. For instance, the one proposed in (Reynolds, 1987) is probably the most famous and most successful model of movement in group. Basically, it is based on a very simple formulation of rules that group's entities must respect. Later, Tu and Terzopoulos (Tu, 1994) developed some research efforts in artificial life with the purpose to populate a marine virtual world. In other approach, Dorigo (Dorigo, 1997) based on systems populated by ants, developed the Ant Colony System (ACS), a general purpose system, which can be used for behavioral associating agents that represent virtual humans. In the same year, Brogan and Hodgins (Brogan, 1997) presented an algorithm to control movements with virtual entities with some "significant dynamic momentum" applied to groups of characters.

Global methods consider the crowd as a whole, characterizing state by fluidity with properties such as density, speed, spatial localizations, and others. We can find examples using this method in (Predtechensky, 1978), and in (Loscos, 2003). In these works they implemented some techniques that allow simulations involving almost 10,000 pedestrian agents in real-time through a macroscopic vision. Many people believe that human behavior is chaotic or at least irregular and not predictable (Helbing, 1997). Helbing et all (Helbing, 2000) proposed a complete model, of physical and social psychological forces management. Latest investigations (Braun, 2003, Musse, 2005) present the generalization of the Helbing model but include more individualism in virtual agents. Bouvier and Cohen (Bouvier, 1995) have used a proposal of a generic system of particles in 3D simulation for simulations flows in a 2.5D human environment. An example of the derivation of systems driven by social forces can be studied in the PetroSim system (Musse, 2005). Earlier, and similar to the concept used in the "Sims" (Forbus, 2001), that use objects or locations linked to specific behaviors, Kallmann and Thalmann (Kallmann, 1998) described the idea of intelligent objects as: objects that provide a plan for its use. Other proposals (Lau Manfred, 2005) (Tecchia, 2001) deal with higher abstractions of the environment, static or dynamic, representing navigation on the virtual environment "already known" in a 2D grid map of heights.

3. Generating virtual characters as agents

The application developed integrates a large number of characters, approximately 10,000 agents, without losing realism. Each virtual actor is independent in the process of decision-making (which characterize generally its individual behavior), and it is able to manage a community of similar entities, "leading them" based on a set of social rules and group community behavior models.

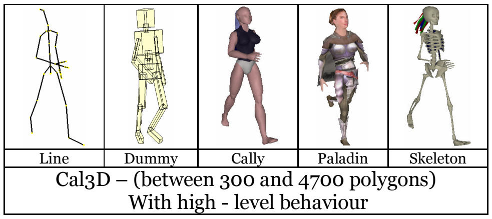


Figure 1 – Some virtual characters allowed by the simulation

Each state of these entities must be maintained in memory, and, in many different situations, is involved with a real time animation. These states have an important role in the "mental condition" of each agent, influencing its decision-making abilities, conditioning its behavior and interaction in a world shared with other agents (Figure 1). All these entities were generated with the Cal3D library (Cal3D, 2004) provided by Bruno Heidelberger.

3.1 Interaction Levels

It is possible to identify a range of abstraction stages in the relationship between high and low level behaviors. In each of the stages will be introduced some capabilities in the virtual entities that we want to hand. Figure 2 shows the “so-called” (and well known) pyramid of computer graphics, where successive levels of abstraction introduce growing "skills" to the entities that we want to manipulate. In this particular case, these entities will be called as agents[1].

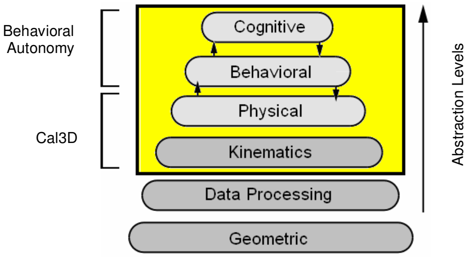
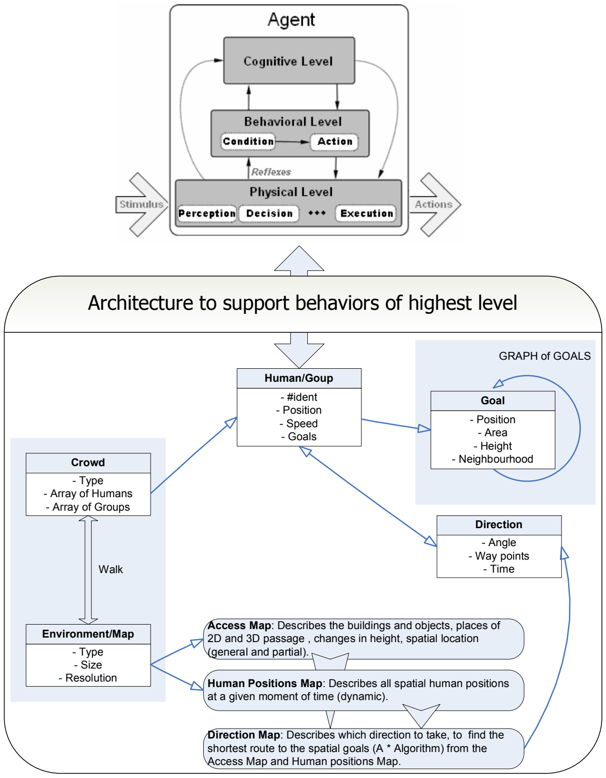


Figure 2 – Computer Graphics Pyramid

The pyramid’s lower layers - physical and kinematics - were implemented with the Cal3D library. The animations created are available for upper layers in an elementary way - the biped movement (walk), for instance. The main domain here is formed by the other layers of the pyramid: cognitive, behavioral and physical; as well the connection between them and with the lower levels. Each level of abstraction provides information to its top level. Similarly, each level controls its lower level.

3.2 A High Level Architecture to Support Behaviors

It is possible to define an internal process entitled by “Agent Module” that represents a virtual character and his (reactive) behavior, and another diagram that project the architecture on which the previous module fits with the surrounding environment. In general, these modules can be represented by the two schemes (Figure 3). In the agent module, we can see the information flowing “for and by” each different agent’s levels, the form how is obtained, the way to process it, and the consequences of that process. The knowledge of the world is represented by other scheme, in which the behaviors of the low level will be designed to describe the architecture that supports the behaviors of the highest level.



Access Map: Describes the buildings and objects, places of 2D and 3D passage , changes in height, spatial location (general and partial).

Human Positions Map: Describes all spatial human positions at a given moment of time (dynamic).

Direction Map: Describes which direction to take, to find the shortest route to the spatial goals (A * Algorithm) from the Access Map and Human positions Map.

Figure 3 – The complete behavioral model

4. High Level Behaviors – State Machine

Usually, any Multi-Agent System (MAS) based on a set of behaviors and their correspondent activities, has a structural and operating complexity quite considerable, which imposes actions and behaviors usually impossible to determine in first stage. Among some examples of well known research processes covering this type of knowledge, are the works of Nick Jennings, Mike Wooldridge, Gerhard Weiss, or G. O'Hare, among many

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[1] This terminology is used in order to identify a higher level of differentiation to avatars comparison.

others (O'Hare, 1996, Weiss, 1999, Wooldridge, 2001).

Nowadays, one of the most common manners of implementing reactive agents is based on the use of state machine languages (Sweetser, 2003). One of the most popular for describing an architecture of the type described here is related with the use of a deterministic finite automata (DFA) (Rabin, 2001) or, more specifically, a transducer, which is no more than a DFA, where each transition can join a symbol of output (Sweetser, 2003). Thus, it becomes an easier structure at the status of a "virtual mind", and can simulate certain behaviors in a successful way. This is only possible because, in each state, there are a number of different associated stimulus-responses. This model of fluency between information and action leads us to the four models interaction schema with the virtual environment (Figure 4).

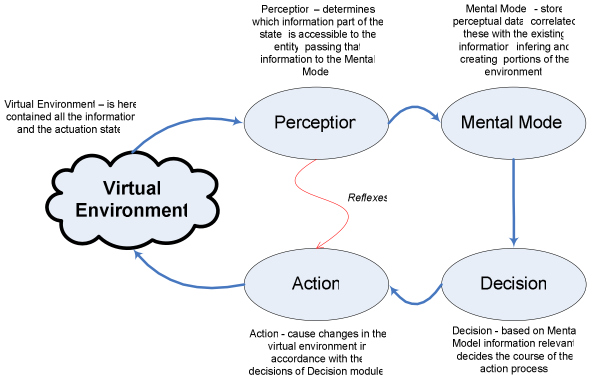

Figure 4 –The four models of AI

5. Behavioral Simulation Tests

In order to test some of the behaviors of the available virtual actors involved with the simulation processes we used a 3D model of an open building structure (Figure 5) as an environment simulation, and two different types of agents ("Paladin" and "Cally" - Figure 1). For each agent is necessary to apply the specification of the animations set provided by the animation library and its association to their realistic actions. It is also important describing the features of the competition actions that will be applied among themselves, which may provide new situations - unpredictable or not.

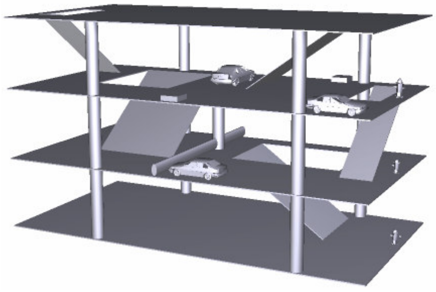

Figure 5 – A 3D Virtual World

Each agent has a set of personal properties that characterize his internal state. These properties can be assigned and used in the algorithm in order to model agent's behavior (eg: run away from an aggressive agent). Such properties may be: the state (stopped or in progress), location (current value x, y, z), destination (destination value x, y, z), speed, strength, sympathy, group which it belongs, etc. The values of these properties can vary on a scale of 1 to 10, in order to provide a (dynamic) trend, in accordance with the parameters of its internal state.

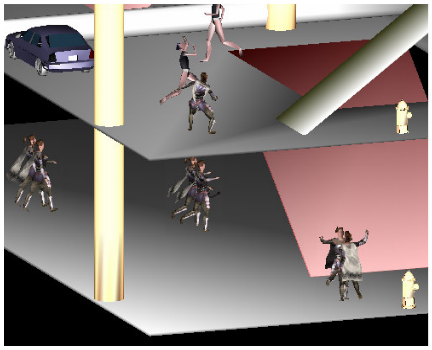

Figure 6– Simulating agents' autonomy specifications

The way how an agent interacts with the world, and with others agents, is established at the behavioral level. The instructions that were defined will be evaluated and a data structure will be created to receive the mental model (the brain) of the virtual character (Figure 4). We may see some of these types of autonomy specifications in Figure 6. In the upper floor, we can find an agent "Cally" and other "Paladin" in a conflict situation. This, after the meeting of the two agents (defined by a detection radius, that can be variable between different types of actors, and their internal condition), produce some hostile behaviors, resulting usually in a fight between them. Not far away (also in a pre-defined radius), another agent "Cally" comes to the hostility area, after confirming (through a perception or an inter-agent communication), with another character belong to the same group, this state of "combat" and a provable need for help. On the ground floor, and at the beginning of the ramp that allows access to the upper floor, we may observe two virtual characters moving and acting independently, exchanging compliments while approaching (simultaneous tasks). Later, they possibly form a group and act accordingly based on this new state. This only happens if their current states be favorable to new relationships. On the ground floor, more characters are acting in group, moving to targeted and specific location specified by the user. Another group pursues them, because they have the initial task to track and respond to behaviors of the group ahead (the leader group).

6. Conclusions

Based on the architecture described in the previous sections, for the simulation of high-level behaviors, we created a definition language to handle virtual characters with some kind of social abilities and conduct rules. This will allow the development of simple and intuitive applications to improve news forms of behavior, which makes the platform especially oriented for creating virtual characters more credible at the behavioral level. Allowing the different components of an agent (and their properties) be accessed by the behavior language, combining the set of instructions from high-level (conditions and decisions) implemented, we had the necessary means to develop a structure with significant potential for use in several application areas. Through the use of transducers, the language allows the creation of "static" scripts, containing a number of actions to be implemented, such as a virtual movie argument. The knowledge of the world, the internal and the external state may create too "dynamic" scripts where the argument is not deterministic, depending only by the situation, time, and internal states. The cognitive system was organized into four very specific modules: perception, mental model, objective decision, and resolution of actions. Each of these modules tries to attach strengths and weaknesses of human perception and its associated cognitive to the processing systems, including instinctive reactions, perception errors, memory deterioration, decisions dependents of context, or inference abilities. We also performed some tests whose results were considered satisfactory, if we think in the possibility of setting actions of complementary groups, with disjoined and competitive behaviors, and setting limits and natural transitions between them. Finally, in terms of appropriateness and scalability, it can be assumed that the platform developed could be used in several areas of activities such as: games environments, crowd simulation, urban facilities environments, or populating historical, archaeological, and social environments.

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