Introduction: Creating Artificial Life in Virtual Reality

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I.1. Virtual Worlds

For about 20 years, computer-generated images have been created for films, generics and advertising. At the same time, scientific researchers, medical people, architects discovered the great potential of these images and used them to visualize the invisible or simulate the non-existing. It was the genesis of Virtual Worlds. However, these virtual worlds had two severe limitations:

- There was very little visual representation of living organisms or only very simple creatures in them
- Nobody could really enter into these worlds: the access to the virtual worlds was looking on 2D screens and 2D interaction.

Today, new interfaces and 3D devices allow us a complete immersion into these virtual worlds or at least a direct and real-time communication with them. This new way of immersion into the virtual worlds is called *Virtual Reality*. At the same time, researchers have been able to create plants, trees, and animals. Research in human animation has led to the creation of synthetic actors with complex motion. Moreover, a new field based on biology has tried to recreate the life with a bottom approach, the so-called *Artificial Life* approach. Now all these various approaches should be integrated in order to create truly Virtual Worlds with autonomous living beings, plants, animals and humans with their own behavior and real people should be able to enter into these worlds and meet their inhabitants.

Artificial Life and and Virtual Reality Edited by Nadia Magnenat Thalmann and Daniel Thalmann

In this introductory chapter, we try to identify the key parameters for creating Artificial Life in Virtual Reality, by referring mainly other chapters of this book. Artificial Life is concerned with biological aspects like *Embryonics* (Mange and Stauffer 1994), a basis of natural mechanism of development of living multicellular beings. Artificial Life also includes living organisms created by rule-based languages (Noser and Thalmann 1994) and topology methods (Françon and Lienhardt 1994) or control of mobile robots (Gaussier and Zrehen 1994). However, this introductory chapter emphasizes the Artificial Life of Virtual Humans (Magnenat Thalmann and Thalmann 1993) in Virtual Reality.

I.2. Artificial Life of Virtual Humans

I.2.1. Why Virtual Humans ?

The fast development of multimedia communication systems will give a considerable impact to virtual worlds by allowing millions of people to enter into these worlds using TV networks. Among the applications of such virtual worlds with virtual humans, we can just mention:

- computer games involving people rather than cartoon-type characters
- computer-generated films which involve simulated people in simulated 3D worlds
- game simulations such as football games which show simulated people rather than cartoon-type characters.
- interactive drama titles in which the user can interact with simulated characters and hence be involved in a scenario rather than simply watching it.
- simulation based learning and training.
- virtual reality worlds which are populated by simulated people.

These applications will require:

- realistic modeling of people's behavior, including interactions with each other and with the human user.
- realistic modeling of people's visual appearance, including clothes and hair

For the modeling of *behaviors*, the ultimate objective is to build *intelligent autonomous* virtual humans with *adaptation, perception* and *memory*. These virtual humans should be able to act *freely* and *emotionally*. They should be *conscious* and *unpredictable*, Finally, they should reinforce the concept of *presence.* But can we expect in the near future to represent in the computer the concepts of behavior, intelligence, autonomy, adaptation, perception, memory, freedom, emotion, consciousness, unpredictability, and presence ? In this introductory part, we will try to define these terms and already identify research aspects in these concepts.

In summary, virtual humans should have a certain number of qualities that are represented in Figure I.1

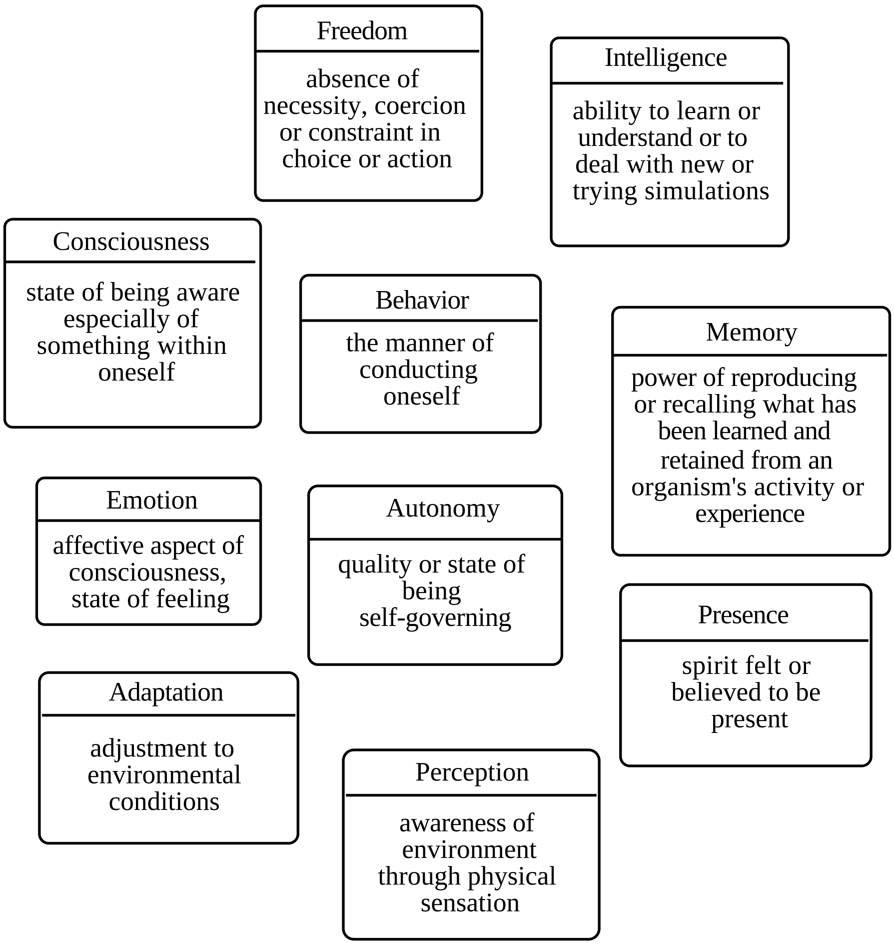

Figure I.1. A few definitions.

Based on classical definitions (Merriam-Webster 1989), we will try first to identify which mechanisms should be simulated in order to implement truly virtual humans or actors.

I.2.2. Behavior

First, virtual humans should be able to have a behavior, which means they must have a manner of conducting themselves. Behavior is often defined as the way in which animals and humans act, and is usually described in natural language terms which have social, psychological or physiological significance, but which are not necessarily easily reducible to the movement of one or two muscles, joints or end effectors. Behavior is also the response of an individual, group, or species to its environment. Based on this definition, Reynolds (1987) introduced the term and the concept of behavioral animation in order to describe the automating of such higher level animation. Behavior is not only reacting to the environment but should also include the flow of information by which the environment acts on the living creature as well as the way the creature codes and uses this information. Reynolds studied in detail the problem of group trajectories: bird flocks, herds of land animals and fish schools.

I.2.3. Intelligence

The classical definition of intelligence is the ability to learn or understand or to deal with new or trying situations. This is also the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria. Implement intelligence in virtual humans means to create artificial intelligence, an area that has always grown for many years, even if there are still considerable limitations, due mainly to a purely logical approach.

I.2.4. Autonomy

Autonomy is generally defined as the quality or state of being self-governing. Rodriguez et al. (1994) introduced the concept of autonomous system: a system that is able to give to itself its proper laws, its conduct, opposite to the heteronomous systems which are driven by the outside. Bourgine (1994) defines an autonomous system as a system which has the abdictive capacity to guess viable actions. As stated by Courant et al. (1994), in cybernetics as well as in cognitive psychology, autonomy has always been strongly connected with self-organization. Hence, computer scientists sometimes prefer to take the following definition of autonomy *"the capacity of a system to maintain its viability in various and changing environments".*

The need to have autonomous behaviour for virtual humans arises from two considerations:

- in computer-generated films, the more autonomous behaviour that is built into the virtual humans, the less extra work there is to be done by the designer to create complete scenarios
- in interactive games, autonomous human-like behaviour is necessary in order to maintain the illusion in the user that the Virtual Humans are real ones.

I.2.5. Adaptation

As defined by Wilson (1991) and Guillot and Meyer (1994), the behavior of an artificial organism, called animat, is adaptive as long as it allows it to "survive" in more or less unpredictable and dangerous environments. For virtual humans, we may consider the general definition of adjustment to environmental conditions and use methods similar to these described by Gaussier and Zrehen (1994) to design control architectures for autonomous robots capable of adapting to an unknown world or the vision-based approach described by Renault et al. (1991).

I.2.6. Perception

Perception is defined as the awareness of the elements of environment through physical sensation. In order to implement perception, virtual humans should be equipped with visual, tactile and auditory sensors. These sensors should be used as a basis for implementing everyday human behaviour such as visually directed locomotion, handling objects, and responding to sounds and utterances. A simulation of the touching system should consist in detecting contacts between the virtual human and the environment. The most important perceptual subsystem is the vision system. A vision based approach for virtual humans is a very important perceptual subsystem and is for example essential for navigation in virtual worlds. It is an ideal approach for modeling a behavioral animation and offers a universal approach to pass the necessary information from the environment to the virtual human in the problems of path searching, obstacle avoidance, and internal knowledge representation with learning and forgetting characteristics. Vision-based behavioral models have been already described by Renault et al. (1991) and Reynolds (1993).

In (Renault et al. 1991), each pixel of the vision input has the semantic information giving the object projected on this pixel, and numerical information giving the distance to this object. So, it is easy to know, for example, that there is a table just in front at 3 meters. With this information, we can directly deal with the problematic question: "what do I do with such information in a navigation system?"

In the context of Virtual Reality, there is an interaction between a virtual human and a real one. In this case, there is no possibility of transferring data structures, and real recognition methods (for example: image understanding) are required to provide the virtual human with a perception of the real human's behaviour. Auditory aspects are also important in this case (Lehnert 1994).

I.2.7. Memory

Memory is generally defined as the power or process of reproducing or recalling what has been learned and retained especially through associative mechanisms. This is also the store of things learned and retained from an organism’s activity or experience as evidenced by modification of structure or behavior or by recall and recognition

To implement a concept of memory into a virtual human is not very complex, as already the memory is a key concept in Computer Science. For example, Noser and Thalmann (1994) propose a dynamic occupancy octree grid to serve as a global 3D visual memory and to allow an actor to memorize the environment that he sees and to adapt it to a changing and dynamic environment. His reasoning process allows him to find 3D paths based on his visual memory by avoiding impasses and circuits. The global behavior of the actor is based on a navigation automata, representing the automata of an actor, who has to go from his current position to different places, memorized in a list of destinations. He can displace himself in known or unknown environments.

I.2.8. Emotion

Emotion may be defined as the affective aspect of consciousness; this is a state of feeling, a psychic and physical reaction (as anger or fear) subjectively experienced as strong feeling and physiologically involving changes that prepare the body for immediate vigorous action virtual humans should be capable of responding emotionally to their situation as well as acting physically within it. Apart from making the virtual humans more realistic, visible emotions on the part of the virtual humans could provide designers with a direct way of affecting the user's own emotional state. Virtual humans will therefore be equipped with a simple computational model of emotional behaviour, to which emotionally related behaviour such as facial expressions and posture can be coupled, and which can be used to influence their actions. To render emotions, most facial animation systems are based on the Facial Action Coding System (FACS) developed by Ekman and Friesen (1975). Kalra and Magnenat Thalmann (1993) redefine emotion as a function of two signals in time, one for its intensity and the other for the color. They propose a model of vascular expressions in facial animation (Kalra and Magnenat Thalmann 1994).

I.2.9. Consciousness

Consciousness may be defined as the quality or state of being aware especially of something within oneself or the state of being characterized by sensation, emotion, volition, and thought. Aleksander (1994) discusses the recent renewal of interest in the question of whether an explanation of consciousness can (Dennett 1991) or cannot (Penrose 1989) be captured by some formal theory. He presents a theory of consciousness centered on the concept of a neural state machine. The theory is based on the conditions that may be necessary to synthesize consciousness in constructed artifact. This is given the name "artificial consciousness".

I.2.10. Freedom and Unpredictability

Freedom is the absence of necessity, coercion, or constraint in choice or action; this is also the power or condition of acting without compulsion In terms of Virtual Actors, Kirsch (1994) proposes to say that an actor is free, when and to the extent that his future behaviour is unpredictable to somebody; this somebody may be the actor himself or somebody else.

I.2.11. Presence and Immersion

Presence is the fact or condition of being present and it is something (as a spirit) felt or believed to be present. This spirit is essential in Virtual Reality. As stated by Slater and Usoh (1994), immersion may lead to a sense of presence. This is an emergent psychological property of an immersive system, and refers to the participant's sense of "being there" in the world created by the Virtual environment system. Astheimer et al. (1994) define an immersive system as follows: if the user cannot tell, which reality is "real", and which one is "virtual", then the computer generated one is immersive.

I.3. Communicating with Virtual Humans in Virtual Reality

Two different kinds of interactivity could be addressed: interaction between virtual humans, and interaction between virtual humans and real ones, a Virtual Reality situation. The first is required for computer-generated films, and the second for games, although in either case both kinds of interaction may be needed. These two kinds of interaction are sufficiently different to require quite different technical solutions. A pair of virtual humans interacting is a closed system that can implemented on different machines as proposed by Singh and Serra (1994) which can be developed by equipping the virtual humans with complementary behaviours, whereas the system consisting of a virtual human interacting with a real human is only partially under control of the designer. In order to support interaction and communication, virtual humans should be equipped with the ability to "recognise" other virtual humans and "perceive" their facial expressions, gestures and postures. There is no need for real recognition or perception, of course, because information from the data structures that define these behaviors in one virtual humans can be passed directly to a second humanoid.

In the context of Virtual Reality, there is an interaction between a virtual human and a real one. As already mentioned, there is no possibility of transferring data structures, and real recognition methods are required to provide the virtual human with a perception of the real human's behaviour. True interaction between the Virtual and the real humans requires a two-way communication between them at the geometric level, at the physical level, and at the behavioral level, as described by Magnenat Thalmann and Thalmann (1991). Consider first a classical example of bi-directional communication: human-machine speech communication. The operator speaks using a microphone, the phonemes and words are recognized by a speech recognizer program that forms sentences. On the basis of these sentences, answers or new sentences are composed. A speech synthesizer generates the corresponding sounds which are amplified and may be heard by the operator.

At the geometric level, 3D devices allow the animator to communicate any geometric information to the actor. For example, the animator may use a SpaceBall to define a trajectory to be followed by the actor. He may use a DataGlove for defining a certain number of hand positions. This possibility may be exploited to create dialogue based on hand gestures (Broeckl-Fox et al. 1994) such as a dialogue between a deaf animator and a deaf synthetic actor using American Sign Language. The animator signs using two DataGloves, and the coordinates are transmitted to the computer. Then a sign-language recognition program interprets these coordinates in order to recognize gestures. A dialogue coordination program then generates an answer or a new sentence. The sentences are then translated into the hand signs and given to a hand animation program which generates the appropriate hand positions.

At the physical level, using a force transducer, a force or a torque may be communicated to an actor who can himself apply a force that may be felt by the animator using a force feedback device (Bergamasco 1994). It is for example possible to simulate the scene of virtual reality where the animator and the actor tug on the two ends of a rope.

At the behavioral level, we consider emotional communication between the actor and the animator (see Figure I.2, Color Section). We may restrict emotions to a few, such as happiness, anger, sadness and consider only the facial expressions as manifestations of these emotions. In such a behavioral communication system or, more accurately in this case, *an emotional communication system*, the animator may smile, his face is recorded in real-time using a device like the living video digitizer and the emotion is detected using an image processing program. The dialog coordinator decides which emotion should be generated in response to the received emotion. This emotion is translated into facial expressions to be generated by the facial animation system. Consider the example where Marilyn smiles when the animator smiles. The difficulty in such a process is to decide whether the animator is smiling based on the analysis of the image captured by the living video digitizer. At present only small images with a rather limited processing is possible with the actual hardware; this implies that the detection of subtleties of the face is not yet feasible.

Magnenat Thalmann et al. (1993) have described such an approach, consisting of recording a real human face using a video input like the Live Video Digitizer and extracting from the image the information necessary to generate similar facial expressions on a synthetic face. The recognition method is based on snakes as introduced by Terzopoulos and Waters (1991). A snake is a dynamic deformable 2D contour in the x-y plane. A discrete snake is a set of nodes with time varying positions. The nodes are coupled by internal forces making the snake acting like a series of springs resisting compression and a thin wire resisting bending. To create an interactive discrete snake, nodal masses are set to zero and the expression forces are introduced into the equations of motion for dynamic node/spring system. Terzopoulos and Waters make it responsive to a force field derived from the image. They express the force field which influences the snake's shape and motion through a time-varying potential function. To compute the potential, they apply a discrete smoothing filter consisting of 4-neighbor local averaging of the pixel intensities allowed by the application of a discrete approximation.

Our approach is different from Terzopoulos-Waters approach because we need to analyze the emotion in real-time. Instead of using a filter which globally transforms the image into a planar force field, we apply the filter in the neighborhood of the nodes of the snake. We only use a snake for the mouth; the rest of the information (jaw, eyebrows, eyes) is obtained by fast image-processing techniques.

I.4. Conclusion

Artificial Life refers to all the techniques that try to recreate living organisms and creatures by computer, including the simulation of behavior processes which result from consciousness and emotions. Virtual Reality means the immersion of real humans in virtual worlds, worlds that are completely created by computer. This means interaction with objects from the virtual world, their manipulation, and the feeling that the human user is a real participant in the virtual world. In the future, most virtual worlds will become inhabited by virtual living creatures and users. Figure I.3 and I.4 (Color Section) shows examples of virtual actors.

Figure I.3. Virtual Actors.

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