MODELLING HUMAN BEHAVIOURS AND REACTIONS UNDER DANGEROUS ENVIRONMENT

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KEYWORDS

Gait Analysis; Ergonomics; Biomedical Modelling; Physiological Modelling;
Human Behaviour Modelling; Human Perception Modelling; Artificial Intelligence

ABSTRACT

This paper describes the framework of a real-time simulation system to model human behaviour and reactions in dangerous environments. The system utilizes the latest 3D computer animation techniques, combined with artificial intelligence, robotics and psychology, to model human behaviour, reactions and decision making under expected/unexpected dangers in real-time in virtual environments. The development of the system includes: classification on the conscious/subconscious behaviours and reactions of different people; capturing different motion postures by the Eagle Digital System; establishing 3D character animation models; establishing 3D models for the scene; planning the scenario and the contents; and programming within Virtools™ Dev. Programming within Virtools™ Dev. is subdivided into modelling dangerous events, modelling character's perceptions, modelling character's decision making, modelling character's movements, modelling character's interaction with environment and setting up the virtual cameras. The real-time simulation of human reactions in hazardous environments is invaluable in military defense, fire escape, rescue operation planning, traffic safety studies, and safety planning in chemical factories, the design of buildings, airplanes, ships and trains. Currently, human motion modelling can be realized through established technology, whereas to integrate perception and intelligence into virtual human's motion is still a huge undertaking. The challenges here are the synchronization of motion and intelligence, the accurate modelling of human's vision, smell, touch and hearing, the diversity and effects of emotion and personality in decision making. There are three types of software platforms which could be employed to realize the motion and intelligence within one system, and their advantages and disadvantages are discussed.

INTRODUCTION

Research into human modelling and simulation is a hot topic. World-wide speaking, there are a few research groups quite active in the area of virtual human including Virtual Reality Lab and MIRALab in Switzerland [1, 2], The Center for Human Modeling & Simulation in University of Pennsylvania, USA [3], and SAMMIE by K. Case's group in Loughborough University, UK [4]. It has been an active research focus at Brunel Design in the School of Engineering and Design, Brunel University. Previous work includes the dynamic modelling of human motion, biomechanics, modelling of the deformation of soft tissue [5], the application of neural networks in human motion modelling [6], human rehabilitation engineering and human modelling in product design.

While human modelling in the University of Pennsylvania was focused on the virtual human TRANSOM JACK™, for training and human factors, Nadia Magnenat-Thalmann's MIRALab and Daniel Thalmann's Virtual Reality Lab emphasized autonomous virtual actors. SAMMIE by K. Case's group in Loughborough was developed for ergonomics, and the aim of HADRIAN is to model individual human's anthropometry and functional abilities to facilitate 'design for all'[7]. There are several other research groups working on virtual human [8], as well as the computer games industry [9]. No reported literature was found on the real-time simulation of human reactions in hazard environment. Thus there is a research gap. Since human beings cannot put themselves under a dangerous environment and run tests, real-time simulation is greatly needed. The real-time simulation of human reactions in hazardous environments is invaluable for military defense, fire escape, rescue operation planning, traffic safety studies, and safety planning in chemical factories, the design of buildings, airplanes, ships and trains.

METHODS

In order to make the modelling and simulation as realistic as possible, the latest 3D computer animation technologies are employed to develop a real-time simulation system. Here "Real-time simulation" has two meanings: one is that in the simulated virtual world, the dimension scale and time scale, human motion and the interaction with virtual environment are exactly the same as in the real world. The other meaning is that virtual human reactions in hazardous environments are unknown (depending on many factors on a random basis), not pre-recorded and then played back. In this sense, it is very different from computer animation. The methods used to develop the system can be outlined as:

Classification on the conscious/subconscious behaviours and reactions

Different behaviours and reactions are classified for different groups of people encountering different hazardous situations, and how the emotion and personality, anxiety and fear affect the decision making. This classification is accomplished through literature review, interview of voluntary students, questionnaires survey, experiments with voluntary students and observation on TV programs and films.

Constructing character body 3D surface models.

One method is using a 3D scanner to scan the body for each character to form 3D surface models. These 3D body surface mesh models are then imported into 3DS Max. These scan generated human body surface mesh models usually need some tidy up, and sometime these tidy up took longer time. Another method is constructing the human body surface model within 3DS Max, "digitally sculpt" human body by modifying Editable Poly surfaces with human body photos as templates. The building of human body surface models takes time but tidy and neat human body surface mesh models are achieved.

Capturing motion postures

Different movements (walking, running, jumping, falling, climbing, crawling, being afraid, scared, astonished, hesitated, shakes, etc..) from different actors/actresses are captured, each actor/actress is typical to represent a group of people (age, sex, weight, height, occupation etc.). A 7 cameras Eagle Digital System from MotionAnalysis Co, USA is used to accomplish the motion capture, and the captured movements are the basis for subsequent 3D computer animation. Each motion capture started with a T pose (Fig. 1), so that later the captured motion data can be conveniently fitted with skeleton model, and then bound with human skin surface model.

Establishing 3D character animation models.

The captured motion data are the 3D coordinates for each marker on human body, and the maximum sample rate can be set up to 2000 Hz. The movement of these markers can be instantly displayed on the screen while motion capture is performing, and played back within MotionAnalysis's EVaRT software. These markers are then linked by lines to form 3D human stick model. Using Calcium tool in EVaRT, a 3D skeletal model is fitted into 3D human stick model. Then the captured motion is represented by the movement of human skeletal model and saved in the form of HTR file. The human skeletal model is exported to 3DS Max, and then bound with human skin surface model. This will form the 3D character animation model. It will be trimmed to start and finish with some common postures so that this animation sequences can be smoothly connected to other animation sequences. All the 3D character models and their animation sequences for different movement are exported from 3DS Max to Virtools™ Dev one by one.

Fig1 T pose at motion capture

Establishing 3D models for the scene.

Some basic environments, like rooms and furniture, etc., already exist in Virtools™ Dev's Data Resources. Some environments and animations for dangerous situations, for example, fire burning, smoke, explosion, collapse, etc., are created in 3DS Max, and then exported to Virtools™ Dev.

Planning the scenario and the content to be modelled.

For each dangerous situation, The 3D entities and their animations for the environment, the characters involved and their animations corresponding to different movements, are organised into corresponding folders in Virtools Dev's Data Resources. The sequence of the events is outlined, the time and space limits of the scene are defined.

Programming within Virtools™ Dev.

Virtools™ Dev is a virtual reality authoring software containing more than 400 predefined behaviour building blocks. The programming can be realized by graphic scripts, Virtools Scripting Language, and plug in C++ code. The programming can be further detailed as followings:

Modelling dangerous event.

The scene and characters are imported to the 3D Layout Window in Virtools™ Dev and positioned according to the Initial Condition of planned scenario. The simulation of a dangerous situation is triggered by keyboard or mouse click. Dangerous signals are sent off by Send Message/Broadcast Message behaviours (building blocks).

Modelling Character's perception.

Currently, a character's visual perception is modelled through Wait Message and Proximity behaviours. When the Wait message behaviour gets the dangerous signal and the hazardous entity enters the range of predefined distance of Proximity behaviour, the character is assumed to have visualised the danger. The character's audio perception is modelled by receiving a sent/broadcasted audio message. The character's smelling perception is modelled by receiving an odor signal subject to a time delay in accordance with the distance spread.

Modelling Character's decision making.

Knowledge base on behaviours and reactions for different group of people encountering different hazardous situation are consisted of many Arrays, and each Array is a text file consisted of columns and rows of data (Integers, floats, text strings, objects). Some of Virtools™ Dev's Logics behaviours on array operation, Boolean operation are used in conjunction with graphic scripts, Virtools Scripting Language, and plug in C++ code through SDK API to model the decision making process. Random and Random Switch behaviours are used to model the uncertainty of human's reactions. Human's emotion is modelled as level of arousal, according to the Yerkes-Dodson law [10], which is an inverted-U curve for level of arousal versus performance. Human's personality is modelled using Eysenck's model of personality traits [10], which are horizontally from stable to neurotic, and vertically from introvert to extrovert. These are all affecting decision making.

Modelling Character's movements.

As a result of the decision making process, animations to represent the character's corresponding movement will be triggered. Fig. 2 shows different scripts are waiting to activate/deactivate. In order to make a smooth transition between different movements, some animation started and ended with the same posture, and some starting posture are the ending posture for other animations. Virtools™ Dev's Animation Synchronizer is used to adjust the speed of the movement (slow down or speed up from the original motion captured movement). Virtools™ Dev's behaviours, such as Character Keep on Floor, Enhanced Character Curve Follow, Character Path Follow, Character Go To, Declare Obstacle, Character Prevent From Collision, etc., are used.

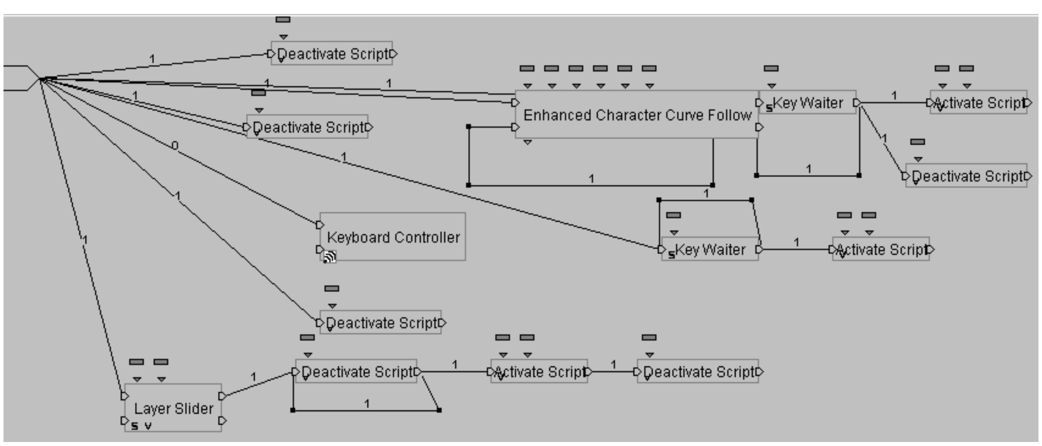

Fig 2 Building blocks and graphic script in Virtools Dev

Modelling Character's interaction with environment.
As the dangerous situation progresses, character is receiving new visual, audio and smell messages, making decisions and reacting accordingly. This is basically repeating the previous three steps described above.
Set the virtual camera accordingly.
Making full use of Virtools™ Dev's camera behaviours and rendering engine, different cameras were set to obit, follow and zoom in and out on the characters. Different cameras were activated according to the progress of simulated event and keyboard input.

Fig 3 Fire and run in an apartment modelled in Virtools Dev

RESULTS AND DISCUSSION

Fig 3 is an example of fire and run scene in an apartment simulated in Virtools™ Dev. In order to model human behaviour and reactions under dangerous environment, there are two major tasks. The first is to model human motion, and the second is to model human perception and intelligence. Currently, human motion modelling can be realized through motion capture system (for example, MotionAnalysis/ Codamotion/ Vicon, etc.) and 3D computer animation software (3DS Max/ Lightwave/ Life Forms/ Maya, etc.), whereas to integrate perception and intelligence into virtual human's motion is still a huge undertaking. Artificial intelligence, expert systems and robotics have been researched for a few decades, and many of these techniques could be used directly or indirectly to model virtual human's perception and intelligence. One challenge here is the synchronization of motion and intelligence, and there must be negligible time delay for the decision making process. Hence the motion and intelligence must be within one system, not two separated system linked together, and the algorithms for artificial intelligence must be simple and fast. There are three types of platforms which could be employed to realize the motion and intelligence within one system. One is the virtual reality authoring software, such as Virtools™ Dev and VRML etc.. Another one is programming under DirectX or OpenGL using C++. The third one is using computer game engine. Using virtual reality authoring software, like Virtools™ Dev, is a quick start, because of many predefined functions (building blocks) ready to use, but often feel the constraints and limitations. Programming under DirectX or OpenGL using C++ has no constraints, but it has to be built from scratch. Computer game engines are supplied with many predefined functions, and each engine may specialise in one type of game. Some of these predefined functions could be used, and many functions need to be redeveloped, and there is less freedom. The authors' opinion is that it is best to start with virtual reality authoring software, like Virtools™ Dev, although finally it may end up with programming under DirectX or OpenGL using C++.

It is a new research area to enable the perception and intelligence, feelings and emotions of a vivid virtual human interactive with virtual world on the computer screen. This new research area is as wide as robotics. Another biggest challenge is to precisely model virtual human's perception. The work reported here is just a beginning. We are currently evaluating the techniques in restricted environments with the intention of extending into other areas.

ACKNOWLEDGMENTS

The authors would like to thank the financial support of the research from HEFCE (Higher Education Council for England) through SRIF2 project BRUN 07/033.

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