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Scripting Human Animations in a Virtual Environment

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Abstract

The current deficiencies of virtual environment (VE) systems are well known; annoying lag time in drawing the current view, environments that are drastically simplified in an effort to reduce that lag time, low resolution and narrow field of view. The scripting of animations is an application of VE technology which can be carried out successfully despite these deficiencies. None of the deficiencies is present in the final product, a smoothly-moving high-resolution animation displaying detailed models. In this animation system, the user is represented in the VE by a human computer model with the same bodily proportions. Using magnetic tracking, the motions of the model's upper torso, head and arms are controlled by the user's movements (18 DOF). The model's lower torso and global position and orientation are controlled by a spaceball and keypad (12 DOF). Using this system the human motion scripts can be extracted from the movements of a user while immersed in a simplified virtual environment. The recorded data is used to define key frames; motion is interpolated between them and post processing is done to add a more detailed environment. The result is a considerable savings in time and a much more natural-looking movement of a human figure in a smooth and seamless animation.

1.0 Introduction

When composing animations portraying moving humans, a way of ensuring natural-looking movements is to capture motion from actual humans [1,2,3,4,5]. Furthermore, placing the person whose movements are being captured in a mockup of the environment which is to be displayed allows registration of position and motion accurately with respect to that environment. We propose the use of a "soft" mockup or a virtual environment (VE) for this purpose.

Human motion can be scripted by specifying individual joint angles or by specifying the goals of the motion and computing the joint angles with an inverse kinematics algorithm [2]. However, the motion produced by both of these methods tends to have an unnatural appearance [6,7,8]. Also, we have found that capturing actual motion takes considerably less time than specifying individual joint angles by interactively specifying movement goals, and produces more realistic motion.

The current deficiencies of VE systems are well known. There are painful tradeoffs between resolution and field of view and between the time it takes to draw the current view and the complexity of the virtual environment [9,10]. Typically one must settle for an unnaturally narrow field of view and a simplified, cartoon-like visual environment. Because the environment in which the motion is captured need only be an approximation of the environment which appears in the final animation, these deficiencies are not a serious hindrance for scripting animations.

2.0 Background

The Graphics Research and Analysis Facility (GRAF) at the Johnson Space Center, Houston, the authors research human modeling as it relates to the human factoring of man-in-the-loop systems. Animations involving human movement are of particular interest for optimizing human performance and for checking consistency and continuity of task designs[11]. Heretofore, the composition of animations involving human movement has been a painstaking operation in which a user at an interactive workstation specifies each movement of each joint. The method of scripting described in this paper results in a considerable savings of time and produces more natural-looking human movements in an animation.

3.0 Description of the system

3.1 Tracking and Computing the Human Motion.

The first phase involves the capture of the tracking information from actual human motion and the computation and display of the resultant motion of the human model within the VE. In order to insure that the models movements are accurate and that its joint angles mimic those of the user, it is necessary for the figure's major anthropometric measurements to be the same as those of the user.

The user wears a head-mounted display (HMD) slaved to the viewpoint by means of a magnetic tracker. The user is personified in the VE as a human model figure with the viewpoint at the figure's eye sites. A total of four trackers suffices to mimic upper-body motion (16 DOF) [1,2,3]; the trackers are positioned on the head, wrists and upper back. The upper-body joint angles are computed with an inverse kinematics (IK) algorithm[6,7,8]. Wrist radial/ulnar deviation is omitted, leaving only 6 DOF for the arm and shoulder making their joint angle computations deterministic; hence the joint angles are rapidly computed and for most motions are constrained to match those of the user. The shoulder complex motion is ignored leading to some error in the motion. Inclusion of the complex clavicle and scapular motion would make the inverse-kinematic computation non-deterministic and difficult to control with one tracker. It is important to note that, in this phase, a simplified VE is sufficient, as long as it contains the visual cues needed for the motion.

The software system is divided into two drawing servers, one reach server, and one magnetic tracking server (See Figure 1). The main client retrieves the current state of the user from the tracking server, polls the spaceball for translation and rotation information, and merges the spaceball information with the tracker information. This information is passed to the reach server which computes the resulting motion in terms of changes in joint angles[12]. The reach server computation is done in a software package called Jack initiated under a NASA university grant by our laboratory at the University of Pennsylvania [6]. The changes in the position and orientation of the figure as well as the joint angle changes of the body are relayed to the drawing servers which update the environment and pipe the needed stereo views to the head mounted display. The advantages of this distributed design is not only speed, but also that any server could reside on any machine on the internet (e.g. tracking information could come from another facility).

The position and orientation of the figure can be controlled by an operator using a six-degree-of-freedom spaceball. Each magnetic tracker matrix is first converted to the coordinate system of the figure (at the base of feet). The spaceball information (relative mode translation and rotation pulses) is accumulated and applied to each of the magnetic tracker matrices in the figure coordinate system. The composite matrices are converted back to global coordinate system to be presented to the inverse kinematic reach server. The scheme allows the figure to be moved by the operator using the spaceball in a natural manner (with respect to the figures coordinate system) while the motions of the user are applied to the human models new translated and rotated coordinate system. The joint angles of the lower limbs can be changed by the operator using the buttons on the spaceball device[1].

3.2 Scripting the Animation.

Scripting the animation involves processing of the captured human motion sequences to produce the key frames of the animation. It requires two people to use the system. The first is the actual personified user with the magnetic trackers appropriately positioned on the body. The second is the operator who will control the position and orientation of the figure in the VE based on the user's requests. The operator will also command the system to write key frames of the animation at appropriate times. The issue of producing an animation that has a realistic time-line is still being researched.

The operator initiates the session by bringing the user to within reaching distance of the specific work environment. The user then performs the activity as prescribed by the task plan. At the operator's signal, the system records the state of every moveable part. The user tells the operator where and how to orient the figure. Upon completion of the session, a file of human motions is produced. These recorded data are used to define key frames; post processing software interpolates motion between the key frames to produce a smooth animation.

3.3 Producing the High Resolution Animation.

The recording of the scripting is done in a simplified VE. Because the post processing is not time-critical, it can use more complex models supplying details that were missing in the VE. The simplified human model is replaced with a high-resolution model and the environment is made much more detailed. The keyfile is then replayed into the animation frame generation program which interpolates between all the key frames. It is also possible to do other special post processing which include texture mapping and realistic lighting (see the section on future work below) (Figure 2).

4.0 Discussion

A narrowed field of view can affect distance judgments adversely [13,14]; however, we found that, within the extent of human reach, it was not difficult to make sufficiently accurate movements. Also, knowing the relative size of objects (i.e. size of hand relative to a workstation screen, for instance) and knowing the approximate location of at least one (your hand) seemed to increase the knowledge of relative distances. One reason may be that stereopsis is a useful distance cue with a person's reach extent [10].

It can be argued that a helmet mounted display is not needed to script the human animations. Scripting an animation using two global views of the human with the user and the operator working the system was tried. When the user tried to view what was being displayed on the monitors, it changed the motion of the human model. There exists an "animation uncertainty principle". That is, the item being measured (the human being) changes as soon as one tries to see one's own changes on a display monitor. In order for a natural looking animation, the user needs to see what they are looking at and working with. It is believed that the more immersed an individual is into the environment, the more realistic the motions will appear. A helmet mounted display provides some of that functionality with some severe limitations.

The user's left and right-eye views can be seen by the spaceball operator on monitors; however, they are not particularly convenient to use when repositioning or reorienting the VE. Hence, a third view is needed which would give the spaceball operator an overview of the action; ideally, the operator should be able to move this viewpoint.

The dramatic effect of realistic motion was caused by very subtle motions. When the user turned her head, there would be slight motions of the waist, and hands. These motions would be very difficult to reproduce manually. When the user looked up, the back would arch by a few degrees and the elbows might swing back.

The spaceball offered a very distinct advantage. The user could stay relatively close to the magnetic tracker source (this is needed for accuracy) and still be "virtually" moved to any location with any orientation within the virtual environment. Moreover, because the HMD and the magnetic trackers have many cables, the user was also safer to stay seated on a chair just moving the head, torso and arms.

With more trackers, we could capture lower body motion also. Walking while tethered with an HMD and magnetic trackers presents some obvious problems. (Perhaps it is fortunate that one does not walk in microgravity.)

5.0 Conclusion

A virtual environment can provide a rapid and convenient way of capturing human motion sequences. Immersion in the virtual environment allows the user to be positioned correctly relative to the environment and to perform accurate reaching movements. A simplified VE can be used to give an adequate display rate for capturing the motion and then replaced by a more detailed environment when the captured motion is used to generate an animation. Other post processing can provide additional special effects in the finished product, a smooth and seamless animation.

6.0 Future Work

Several extensions of this work are planned for the future.

We intend to allow the figure and user to have different bodily dimensions; thus, for instance, we will be able to script movements for the 5th and 95th percentile individuals so beloved of human factors engineers.

A right-handed CyberGlove has already been incorporated into the system. The CyberGlove senses the motions of the joints of the hand (18 DOF). It gives 2DOF for the wrist, supplying the missing wrist radial/ulnar deviation and leaving only 5DOF for the arm and shoulder IK algorithm. Once a left -handed glove is acquired, animations involving both hands will be done.

There is no limit to the amount to the post-processing that can be done once the motion is captured. For instance, the Radiance algorithm is used in the GRAF to do realistic light computations [15]; we would like to use it to provide realistic lighting for the animations. Additional texture maps, or more detailed texture maps, can also be used. If needed, a texture map based recursive animation (animation inside an animation) could be created to reflect, for instance, changing views on a monitor of the Space Shuttle cargo bay operation. This animation could be displayed with texture maps on a monitor within the environment.

Collision detection would be a real convenience in the VE to ensure that the reaches are accurate. Collision detection is computationally expensive, but even a restricted form of it would be useful in the detection of the intersection of one point at the end of the user's extended finger with any of a set of "reachable" objects [16].

It is possible to record the animation with a viewpoint different from the user's, or with a different field of view. One possibility is to allow the viewpoint to move and to specify its position interactively as the animation frames are produced.

Two viewpoints from the recorded data could be reconstructed and used to make a stereo presentation of the animation that could be viewed with the HMD. Synchronization of the two images requires some special measures.

Finally, as soon as we acquire more trackers, we intend to put a second user into a VE.

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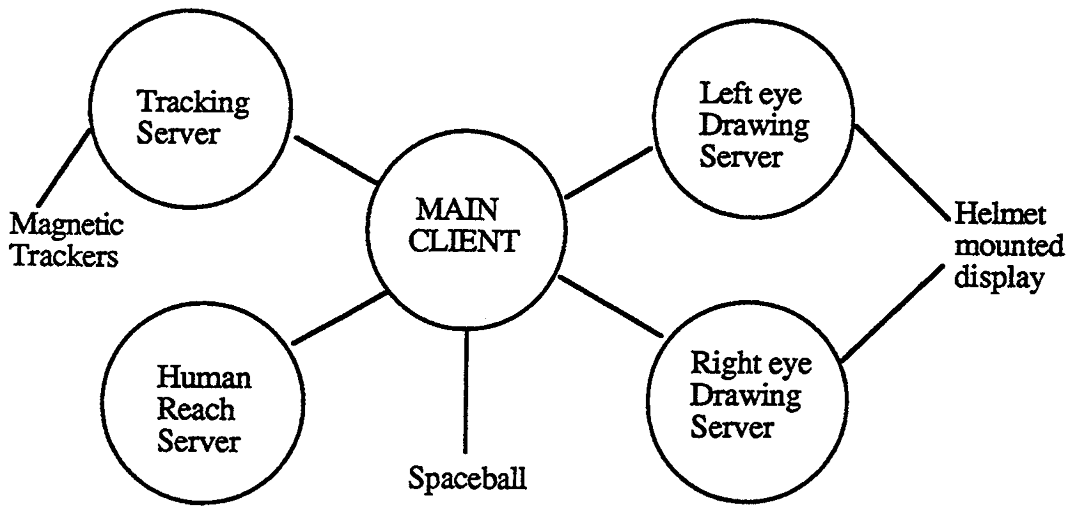

Figure 1- Software/Hardware System Configuration (All servers and clients run on Silicon Graphics Workstations).

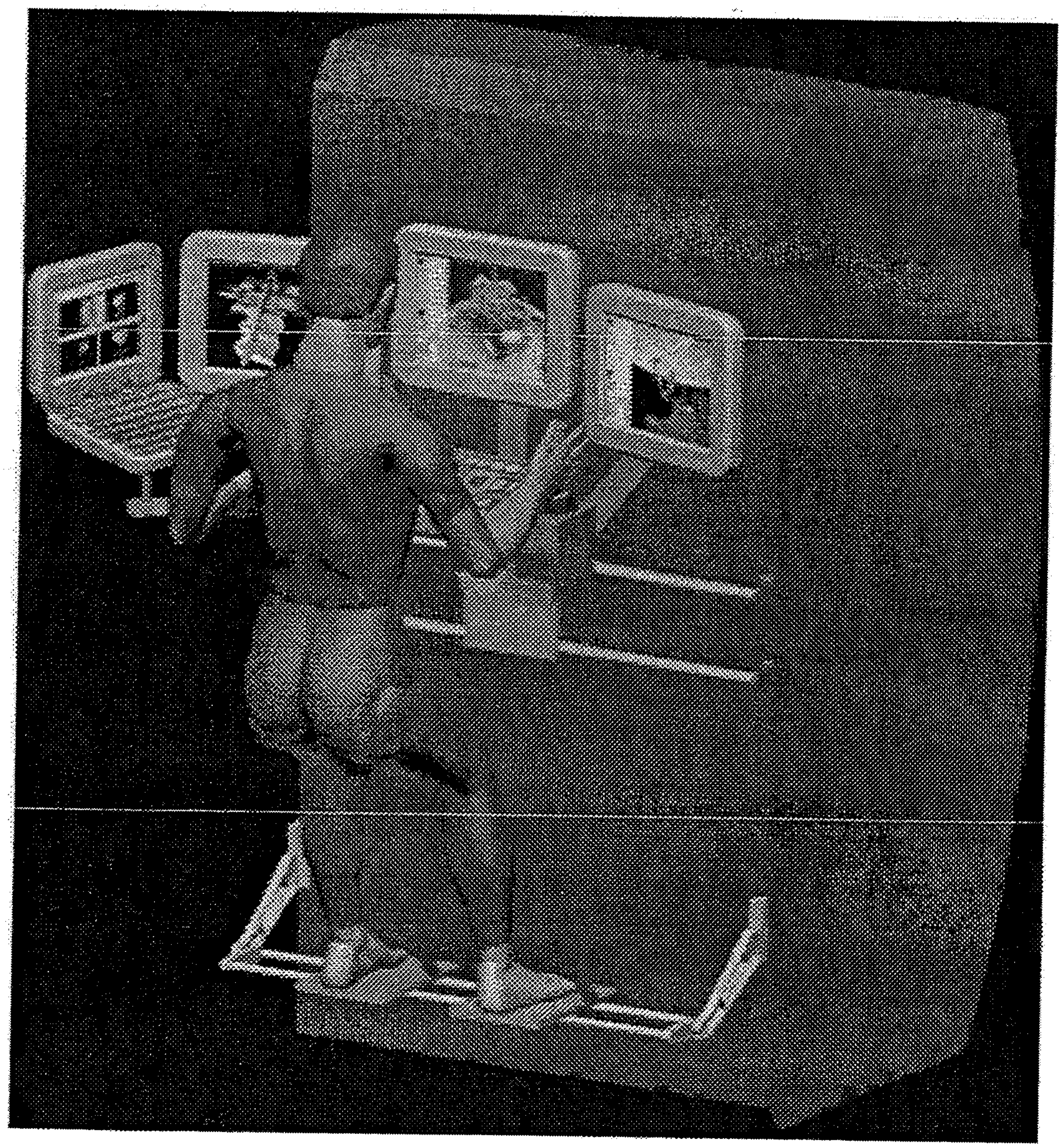

Figure 2. High resolution human model working at a space station workstation.

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The Fourth International Symposium on Measurement and Control in Robotics (ISMCR '94) Topical Workshop on Virtual Reality was organized to respond to the growing interest and importance of the niche area of virtual reality in the field of telerobotics and supervised autonomous robotics. The Symposium, organized by IMEKO Technical Committee 17, sponsored by the AIAA/IEEE/ISA, and hosted by the Clear Lake Council of Technical Societies and the NASA Johnson Space Center attempts to bring together a comprehensive international overview of the rapidly moving advanced technology which comprises the field of virtual reality. This focused Symposium deals with each of the critical technology areas in an integrated fashion, such that advances, problems and issues which cut across technologies can be viewed and evaluated from an integrated, common perspective. Papers in the areas of *rendering, tracking sensors, displays, sensory feedback,* and *applications* are included in the six sequential sessions of the Symposium. It is felt that this Symposium provides an important and timely indepth look at the interaction of these technologies as they apply to the applications of virtual reality to robotics.

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