Three-dimensional virtual human in the military criminal investigation training system

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Abstract

To improve the fidelity of virtual human model, at the same time to ensure continuity of human movement and to reduce the size of the model impacting on system performance, combined with multiple software and algorithms to solve the conflict between the two. According to three-dimensional virtual human in the military criminal investigation training system, create geometric model in Poser, simplify under the premise of its fidelity, set DOF nodes in accordance with DI-Guy's joint requirements, and build skeleton that the human model is handled as multi-body system. Deal with cracks while human movement, and ultimately a variety of the characters and their animation in the system are completed. The instance shows that: The model created in Poser can still maintain a better fidelity after simplification, build skeleton and debug human movement in DI-Guy, the approach overlapping can be used to solve model cracks. This method can largely improve the fidelity of character models and reduces the size of the model, thus improving the coherence of human movement and system operating performance.

Keywords: Virtual human; DI-Guy; DOF; Poser

1. Virtual human technology research

Current geometric modeling and motion control technology of virtual human become more and more mature and perfect. The most obvious example is the application of a series of newly introduced three-dimensional animation films like "Avatar", both the appearance of virtual human and action simulation are very realistic in the movie. Geometric model representation of human body usually has the following [1][2] method: stick model, surface model, body model. Geometric representation of a virtual human must meet the fidelity requirements of three-dimensional virtual human appearance, behavior characteristics and other aspects, including the human body and human appendage modeling.

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Virtual human motion control\textsuperscript{[3][4]} study is designed to achieve realistic virtual human animation and movements. Current major research focus is virtual human body movement and the virtual face movement.

Human motion is a dynamic feedback control process, and it is assort with vision, vestibule feedback, not only influenced by gravity, inertia and other physical laws, but also by emotions, hobbies and other individual factors. Virtual human motion simulation must first solve the problem of fidelity and common methods include:

1. Parametric key frame technology: This method is simple and practical to calculate, the cost is very small and is used in the vast majority animation software. Drawback is the animation generally suitable for simple objects animation generation.

2. Kinematics: Including FK (Forward Kinematics) and IK (Inverse Kinematics).

3. Procedural Methods: Because this method in the modeling has been extracted based on the true characteristics of human motion, the simulation of human motion has a good sense of fidelity. However, the application scope of this method is limited. Generally used for simple and easy modeling exercise, it is difficult to promote to the general movement; Animation detail is generally controlled by the internal algorithm, which is difficult to adjust.

4. Dynamics: It uses a combination of kinematics and dynamics to control the movement of virtual human, but fidelity cannot fully meet the requirements.

5. Motion Capture: The biggest advantage is the ability to capture the real human motion data and the effect is very realistic. This method began from the 1990s and is considered the most promising method of motion modeling.

2. Realization of virtual human in the military criminal investigation simulation training system

2.1 Geometric modeling of virtual human

The geometry model of characters involved in the Military Criminal Investigation Simulation Training System are created in "character style master" Poser. Poser characters are exported as .3ds format, choosing the right clothing, hairstyle and so on.

The models exported from Poser are realistic and exquisite, however, models often contain millions of patches. These model are not conducive to join to the system, the texture are not easy to deal with. Character model requires not only mathematical precision, but also to achieve realistic visual effects (real-time, interactive) during the character motion process. In order to improve the display speed of the model, it need to reduce the complexity of the model, make real-time scene rendering to be possible, so it can maximize the improvement of visual effects.

The simplifications of character models in the system are mainly adopt the cut method\textsuperscript{[5]}. Decimation mainly implemented by reducing and combining the point, edge, face and other basic elements of the initial model. Most of the current three-dimensional models are transformed into triangle mesh, according to the triangle mesh geometry and topology characteristics, simplifications can be combined with three different methods\textsuperscript{[6]}: vertex cut method, while contraction, and patch contraction.

The patches number of the model has been simplified becomes gradually reduce, but eventually ensure the human fidelity. Fig.2 shows, from left to right the number of model patches as follows: 1、154485, 2、82792, 3、72144, 4、22924, 5、13697.

Another important work is the modification details for different characters model, such as military clothing with badges, collar flowers, badges, name cards and other decorations, and different levels of military badges, shoulder patches, etc. are different, it need to be reflected on the details of dresses. Such as legal medical expert needs a white coat, the suspects wear different colors in order to pursue the fidelity of the system. These details are in the system are achieved by three-dimensional modeling. Fig.3, the simplified character renderings, a captain model has been dealt with, its badges, armbands, collar flowers, name cards and other details are clearly visible, remains a good fidelity after simplification.
2.2 Virtual human motion control

2.2.1 Virtual Human skeleton modeling

Multi-body System is a large range of relative movement of multiple objects (rigid or flexible) connected by kinematic pair. If each object is rigid, multi-body system called Multi-Rigid-Body System. Virtual human can be considered as a rigid multi-body system that various bones connected by joints, and there is relative motion among them. If the human body physiological range is not be considered, and assuming the length and the shape of skeleton remains the same during the exercise process, then the joints can be reduced to rigid mechanical rotation hinge, the body skeleton can be simplified as a rigid, so it can be further considered virtual human are only the rigid multi-body system that the relative rotation exists during various parts of the body. This thesis will treat virtual human as a multi-body system for the analysis and research.

Human skeleton model is mainly constituted of the joints and bones. The joint as a point, the joints between the bones as a chain, according to the interlocking relationship between the bone and joint of human physical models, the body can be linked. The complex structure of the human body has 200 bones. For modeling, it is necessary to abstract and simplify the body's bones and joints. The human body is divided into 16 body segments, respectively, upper body, neck, head, left arm, right arm, left arm, right lower arm, left hand, right hand, left thigh, right thigh, left leg, right leg, left foot, right foot, connected by 15 joints, respectively, the hip, left shoulder, right shoulder, left elbow, right elbow, wrist joint, wrist joints, chest neck joint, neck joints, root joints left leg, right leg the root joint, left knee, right knee, left ankle joint, ankle joint. Figure 3 shows the bone structure defined in DI-Guy, the model will be set according to this diagram to control the body motion.

2.2.2 Debugging human motion control
Currently, there are two main controlling methods of human physical model motion. One is controlling by the joint, the other is controlling by skinning. Skinning is the assembly of bones and skin controlling technology. Bone can be controlled by forward dynamics and inverse kinematics. Assembly of human physical model and bones is called the skinning, and human patch model will exercise with the skeleton. The skinning technology has some drawbacks: the animation is controlled by the keyframes, and the output rendering processed images are joined into animation. So the model patches amount become very tremendous to ensure the model to be realistic; the virtual world requires particularly fast refresh rate, so inevitably asked to use the fewest facets to represent the most details. So the model used the skinning technology, the environment is bound to depress the refresh rate.

Joint controlling is to establish three-dimensional model of the human body directly, set up degrees of freedom (DOF) of the joints, and control human physical model by degrees of freedom. In this way the problems is the model appear cracks when movement, so the body motion controlling will be distortion and effect is unconspicuous.

This thesis adapts the first approach joints controlling to control three-dimensional virtual human. In order to display human motion in DI-Guy properly, it need to create skeleton structure. Fig.3 shows the skeleton structure defined in DI-GUY, it selects the human body model as the topology figure and controls the virtual human motion by joint variables. It can be see that each circle represents the joint definition, the line represents all parts of the human skeleton segments. Blue font represents physical model of the human body parts and physical models are linked by the joint, which means that the physical model and the joint variables are connected.

2.2.2.1 Joint node setting

In the skeleton model, there is a root joint, which is located in the center of the pelvis. Fig.3 shows it is the parent-child relationships between joints and bones. Bones father and son are joints, the bones have only one father and can have more than one son, except that the terminal bone has not a son at all; the joints has a father and a son except the root joint has not a father at all. Set up human body model DOF node as showed in Fig.3. Human motion is completed together by a number of joints and bones, and the movement of one joint is connected with the next joint. In DI-Guy, the joint degree of freedom is a very important concept, which determines the required number of independent variables of the joint structure state. Each joint can have up to six degrees of freedom, namely three directions of movement and three directions of rotation, and joint range of activities is subject to certain restrictions. Human body has 15 joints in DI-Guy, 14 of the joints have three degrees of freedom DOF, that is, the joints can rotate around X, Y, Z direction. Such as the knee can rotate and swing. Knee is the most typical of the three degrees of freedom, so it can rotate around three different directions. In addition, the base joint has six degrees of freedom and it can rotate and move in space. The built model hierarchy structure is showed in Fig.4.
According to the study of anatomy and body measurement results, set the joint rotation range of human body model as the table:

| joints         | Activity status                        | Rotation range | joints         | Activity Range               | rotation Range |
|----------------|----------------------------------------|----------------|----------------|-----------------------------|----------------|
| Neck joint     | bow \ raise head                       | 40~35          | Knee joints    | Forward swing, backward swing | 0~135          |
|                | left distortion and right distortion   | 55~55          | Ankle joints   | Up swing, down swing         | 110~55         |
|                | left turning, right turning             | 55~55          |                | External rotation, internal rotation | 110~70         |
| Chest joint    | bend forward, bend backwards            | 100~50         | Shoulder joints| External swing, internal swing | 180~30         |
|                | Left bend, right bend                   | 55~50          |                | Up swing, down swing         | 180~45         |
|                | Turn left, turn right                   | 50~50          |                | Forward swing, backward swing | 140~40         |
| Pelvis joint   | bend forward, bend backwards            | 120~15         | Elbow joints   | Bending, stretching          | 145~0          |
|                | Outside turn, inside turn               | 30~15          | Wrist joints   | External swing, internal swing | 30~20          |
|                | Outside rotation, inside rotation       | 110~70         |                | Bending, stretching          | 75~60          |
To control the joints can be realized by the DI-Guy API function interfaces. Using the API function interface can solve the shortcomings that users can only use fixed action in DI-Guy, and the action has been effectively extended. The hierarchy structure of human models has been set up, and custom characters can be added into DI-Guy. In order to control human motion in DI-Guy, it needs to configure the corresponding joint variables defined in .cfg file, then API function can visit the joint correctly. Table 2 shows the joint variable definition of the right arm:

Table 2 defines the human right arm three joint variables

| Variable | Definition                      |
|----------|---------------------------------|
| uarm_l shoulder_l_rz | Definition of left shoulder rotation variable in Z direction |
| larm_l elbow_l_rx | Definition of left elbow rotation variable in X direction |
| larm_l wrist_l_ry | Definition of left wrist rotation variable in Y direction |

As a result, the defined joint variables can be accessed by DI-Guy API interface functions. According to joint rotation range and degrees of freedom, the joints can be real-time motion controlled. The example showed in Table 3.

Table 3 Example for real-time motion controlling by API functions

```c
DI-GuyCharcterPoseOverride* pose_override=Null; //Create an action overload variable in DI-Guy;
Float *pose_array=Null; // Action array;
Float* weights_array=Null; // Control the speed of human motion;
Int shoulder_l_rz_index=-1; // Left shoulder in the Z direction;
int shoulder_l_rx_index=-1; // Left shoulder in the X direction;
... //Other joints;
Shoulder_l_rz_index=pose_override->get_var_index("q. shoulder_l_rz"); // Get the left shoulder;
Pose_array[Shoulder_l_rz_index]=cos(t); //Custom joint motion equations and it can be changed to the data received from the device;
... // Other drivers of human joints;
pose_override->set_pose_in_radians(pose_array, weights_ar-ray, 0.0); //Drive character.
```

2.2.2.2 Crack solution

Geometric models created by Poser vividly realized human geometric features, however, joints often crack when debugging the motion of characters in DI-Guy, it cannot properly reflect human motion which is implemented by the joint animation. If the human geometry models have not been resolved, the fidelity of human motion will be heavily depressed.

In this regard, the method that the models overlap at joints will be adopted to resolve the problem. As showed in Fig.5, though in the method joints still crack in the larger scope action, such as the hands rising up, human motion is smaller scope in the military criminal investigation training system, it can meet the motion requirement, as showed in Fig.6

Figure 5 joints overlapping grid
Figure 6 Cracks of the joints when large scope motion
3 Three-dimensional virtual human models in the military criminal investigation training system

3.1 The system requires 13 virtual characters, and the requirements of static modeling and motion of each character are different, specific details as follows:

Table 2 character modeling requirements

| No. | Name (Duties)                      | Date of Born | Static modeling requirements | Description of characters in system and static modeling requirements | Action requirements                                      |
|-----|-----------------------------------|--------------|------------------------------|---------------------------------------------------------------------|----------------------------------------------------------|
| 1   | ZhangYang                         | 1990         | 3D                           | Suspects                                                            | Sitting in interrogation rooms for trial, words and expressions |
| 2   | ZhangYan                          | 1979         | 3D                           | Suspects                                                            | Sitting in interrogation rooms for trial, words and expressions |
| 3   | WangLi                            | 1980         | 3D                           | Suspects                                                            | Sitting in interrogation rooms for trial, words and expressions |
| 4   | XuBing                            | 1988         | 3D                           | Suspects                                                            | Sitting in interrogation rooms for trial, words and expressions |
| 5   | XuLei                             | 1990         | 3D                           | Soldier, injured in the hospital                                    | Lying in bed, words and expressions                        |
| 6   | WangJiuli                         | 1981         | 3D                           | Captain, 5 years military service                                   | Standing, the body fretting, words and expressions         |
| 7   | Lierhu                            | 1971         | 3D                           | Eyewitness                                                          | Standing, the body fretting, words and expressions         |
| 8   | Master Li of Security Department  | 35-40        | 3D                           | Colonel, 23 years military service                                  | Sitting and answering the phone, standing report to the Director(showed in figure 11) |
| 9   | Officer of Security Department    | 20-30        | 2D or 3D                     | Two, Captain                                                        | Standing, words and expressions                           |
| 10  | Master of Political Department    | 50-55        | 3D                           | Major General, 35 years military service                            | Sitting, answering the phone, words and expressions         |
| 11  | Forensic                          |              | 3D                           | White coat                                                          | Sitting, words and expressions                            |

3.2 Results of three-dimensional virtual human motion

There are a series of events in the system, intercept one of the character animation pictures to be an example. Characters are all three-dimensional modeling in the Fig.7, and animations have been implemented in accordance with system requirements.

4 Summary and prospect

The military criminal investigation training system is to simulate the military criminal investigation training process, in which the characters are required to be three-dimensional. The thesis researches applications of characters modeling and motion controlling technology based on DI-Guy, DOF etc. More complex model need to be optimized, since this requires further work.
Figure 7 The Political Department chief reports to the politics department master

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