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Review of constraints-based motion retargeting techniques in 3D animations

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Abstract— **Constraints-based motion retargeting was one of the motion retargeting techniques. With it, a collection of constraints were set when the 3D motion data were reused to object models during animating. The existing main techniques of constraints-based motion retargeting are analyzed and compared first, and then the problems are proposed to provide reference for further researches.**

Keywords: Motion Retargeting; Constraints-based; Inverse Kinematics; Space-time; Physical Laws

I. INTRODUCTION

Human motion is one of the popular issues in the area of computer animation[1] in recent years. Realistic motion data can be captured by recording the motion of a real actor with a motion capture system, and then motion retargeting will adapt these motion data to new characters, which will be real-time, reality and high quality. However, the motion capture approaches suffer from simple and noisy motion data, and monotonous captured motion style. What is more, the retargeted motion will lose the characteristics when the size and proportions of virtual actor are different with the real one. Constraints-based motion retargeting modifies the original 3D motion data first and then reuse it to new characters with some constraints to keep the animation effects, which is of great significance for computer animation.

II. RESEARCH ACTUALITY

A constraints-based approach which motion retargeting is made between similar bone structures that are similar topological structures, but different sizes was proposed by Michael[2, 3]. However, this method ignored dynamics constraints which were crucial for some motions. So, Popovi’c and Witkin[4] put forward a motion editing technique based on physical laws. Different with the method proposed by Gleicher[5], which sacrificed the physical laws of motion to ensure the solvability, this one simplified the topological structure of the role to reduce the difficulty. Choi came up with a real-time motion retargeting algorithm, which was based on the inverse kinematics, and was realized through calculating the end effector’s and joint’s positions of role model[6]. And this method could realize the retargeting between roles with different bone structures keeping the features for original data. In order to solve the retargeting problem caused by completely heterogeneous roles, Jean - Sebastien Monzani presented a method combined with transition model and inverse kinematics[7]. Nevertheless, it was only suitable for roles with less joint degrees and the mapping relationship was too simple to ignore the physical constraints, thus being lack of physical realism. Rama Bindiganavala and Norman I.B Adler adopt the space constraints-based method and they put forward a improved one that was zero-crossing of the second derivative was used to get the major changes during motion detection[8].This method was usually used to detect the boundary of static image and then establishing the sensor to track the joint movement with great variations, and last combining with visual attention tracking and inverse kinematics to strengthen constraints.

Luo[9] adopted the inverse kinematics and numerical optimization to get the motions which meet some space time constraints, retained the features of the original motion and simultaneously could create new actions as required. Wei[10] simulated more complex human hairspring by transforming the Newtonian mechanics to objective function, combining with space-time constraints-based method. Ming[11] put forward a method that established a unified skeleton model and then manually designated the matched bones to correct the initial position of skeletal, and this method could realize the motion retargeting and transition between different skeleton models. Yang[12] proposed a motion retargeting between models of same skeletal structures but different sizes with inverse kinematics.

III. BASIC THEORY OF MOTION RETARGETING

A. Basic Concept of Motion Retargeting

Motion retargeting is reusing the motion data by mapping them to other object models. Motion retargeting makes it possible that the same motion capture data are used to drive different role models to make the same actions without heavily work for creating key frames by animators. Motion capture techniques can be applied to record the details of human joint motions to build a full motion capture database. However, there are two difficulties for using capture data fully[13]:

- The data get by high speed sampling systems are so huge that it is very time-consuming for animators to modify the motion data frame by frame.
- Each joint trajectory is calculated according to the figure of performers, therefore, there are some mistakes such as levitation, penetration and glide if the capture data are directly used to another models of greatly different sizes, causing some data missing to some extent.

Constraints-based motion retargeting not only can reuse the capture data, but also can solve other problems[14]:

- Changing intention: Original ideas can be changed as need during the animation production process .
- Making difficult motions: Difficult motions which are hardly caught can be shown through the motion editing and retargeting to make animations be of high quality.

There are three main constraints-based motion retargeting techniques at present, which are inverse kinematics constraints-based method, space-time constraints-based method and physical constraints-based method. They will be introduced in detail in the following.

B. Introduction of Human Model

The human model is used to simulate the human motion, and the structure of it directly influences the accuracy of the motion description. That is the important details of motion will be lost if the structure is too simple and it is difficult to apply the structure if it is too complex. The general model is one of 16 joints and one root node shown in Fig.1, and so the motion of human can be simplified to the motion of the following model.

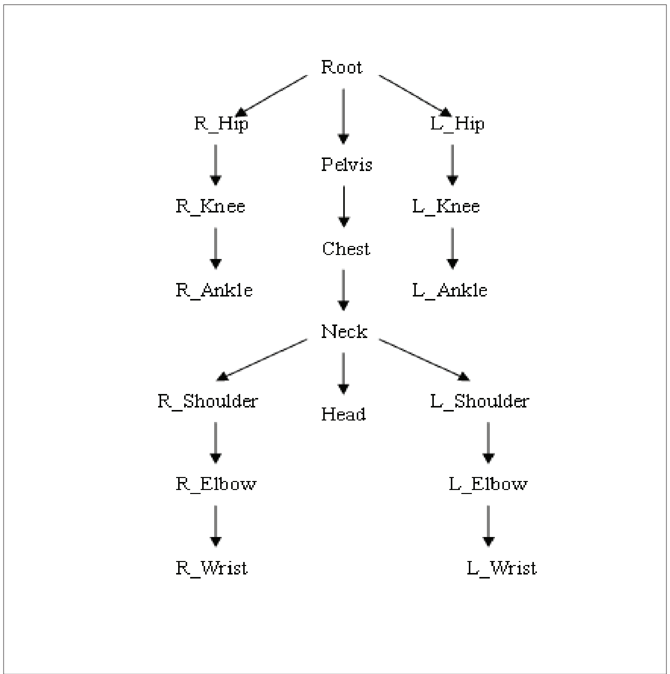

Fig.1. Human Skeleton Model

C. Description of Human Motion

The human skeleton model is like a tree and the root of the tree is treated as the root node of the model, and other nodes of the tree correspond respectively to other joints. The whole motion consists of translation and rotation. That is the translation of root node and the rotations of other nodes around their father nodes. The root node is rotated first, which controls the motion direction of model and then other nodes are rotated around the coordinate system as the coordinate of their father nodes as the origin of coordinates. The position of each node under the global coordinate system can be get by Eq.1:

$$Pk(x,y,z)=T_{root}R_{root}T_2R_2\ldots T_iR_i\ldots T_kR_kP_0(x,y,z). \quad (1)$$

In Eq.1, Pk(x, y, z) is the position of node k($2 \leqslant k \leqslant n$, n is the number of nodes) under the global coordinate system. P0(x, y, z) represents the relative coordinate position of node k under the coordinate system where as the coordinate of its father node as the origin of coordinate. Ti($2 \leqslant i \leqslant k$) represents the translation component of node i from current coordinate system to father-node-based system. Ri is the rotational vector of node i around its father node, where the rotational vector consists of three rotational components that are x, y and z. The position of the node is determined by two of the three rotational components and then the motion direction of the skeleton is controlled by the third one which is called torque component.

IV. CONSTRAINTS-BASED MOTION RETARGETING TECHNIQUES

A. Inverse Kinematics Constraints-based Technology

There are two kinds of kinematics that are forward kinematics and inverse kinematics[15].The end joint or the end positon of skeleton is regarded as the end effector in animation. Using forward kinematics, the translational and rotational vector of the end effector can be solved according to the given gesture. On the contrary, using inverse[16] kinematics, the positon and direction of father joints can be get reversely according to the end effectors.

Inverse kinematics constraints-based method has become the most widely-used measure of motion retargeting. Just one frame is edited with some constraints by this method each time and so the editing is rather fast to meet the requirements of interactive motion editing. The basic idea of inverse kinematics is simplifying the editing problem by using inverse kinematics to any two joints but not the whole skeleton. The method can produce interactive motion warping by optimizing constraints, including controlling the centric track.

The inverse kinematic solution can get the editing results which meet the position constraints of intra-frame well. But it ignores the continuity constraints between adjacent frames so that there will be jogs in objective motions. In addition, there will be no results when the position constraints are set unreasonably. In order to keep continuity between adjacent frames, Jehee Lee[17] put forward a method combined inverse kinematic and filter, where low pass filter was used as the post processing to reduce the jogs of adjacent frames to realize the continuity.

B. Space-time Constraints-based Technology

The basal principle of space-time constraints-based technology is that space-time constraints and objective functions are used to avoid the unnecessary or unexpected changes during motion retargeting. Global optimal solution can be obtained by this method and it can satisfy both space and time constraints, which proves that this method is rather suitable for reusing the capture data. The difference between the space-time constraints-based technology and other constraints-based technologies is that the whole motion or part of the motion instead of each frame is calculated each time with the former method.

In the early work[18,19], physical laws were used as the constraints for motions first and then the amount of energy muscles would expend during the motions was regarded as the objective function and finally new motions which could drive the single model to do some simple motions under the physics laws were get with least energy consumption.However, using mathematics to describe the motion was extremely challenging and so the method mentioned above might not work.Even though space-time constraints-based technology make it possible that the high-level properties are regarded as the standard of motion, some abstract properties such as angry and grace can still not be realized by this method.What is more, it is a complex computer simulation, that in itself is a complex computer simulation which is inefficiency.

C. Physical Constraints-based Technology

Some specific and useful constraints have been applied in physical constraints-based technology. Though some physical laws are easily defined as the space constraints, many such as dynamic constraints and energy laws will be ignored in view of the performance of algorithm, for that it is too hard to calculate them under the frame of space-time constraints. Popovic and Witkin[4] proposed a technology based on the physical laws which could simplify the problems with topological simplification. Pollard[20] came up with a simple and rapid real-time motion retargeting method that was motion data could be zoomed under physical laws combined with mass-spring model and inverse kinematics, but it would result in large errors. Bruderlin and Calvert[21] put forward a hybrid method with combinations of objective-based and dynamics motion-controlled methods, thus helping animators control the motions interactively. The biggest advantage of the physical constraints-based technology is that it can simulate the interaction between objects automatically. But because of the complexity of computing, few scholars have gone deep in the study of it. And it is not applied in practice but just some experiments such as extending each periodic motion of walking to a full motion..

V. Conclusions

Three main constraints-based motion retargeting techniques are introduced in this paper. Among them, inverse kinematics constraints-based method and space-time constraints-based method are mature, while physical constraints-based method is still the emphasis and difficulty of study. It is very hoped that there would be a further research for the physical constraints-based method on the basis of analysis in this paper, combining with inverse kinematics and space-time constraints-based technologies to make the motion retargeting more smooth and flowing.

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