A Multi-functional Visualization System for Motion Captured Human Body Based on Virtual Reality Technology

Qichang He[1], Lifeng Zhang[1], Xiumin Fan[1,2], and Yong Hu[1]

[1] CIM Institute of Shanghai JiaoTong University, Shanghai 200030, China
[2] State Key Laboratory of Mechanical System and Vibration, Shanghai 200030, China
heqc@sjtu.edu.cn

Abstract. This study is to develop a multi-functional visualization system (KINE) for motion captured Human Body based on Virtual Reality (VR) technology, which reconstruct the skeleton rigid model motion in the 3D virtual environment. The KINE is based on VR general application development platform named VRFlier, which provide an innovative human-machine interaction. This paper focuses on the methods of human rigid modeling and motion reconstruction. The human rigid modeling is based on Rigid Body Assumption (RBA) theory and using Virtual Marker (VM) to position the arthrosis of linked body segment. The motion reconstruction is implemented through coordination transformation of Local Coordination System (LCS) defined by VM. KINE is applied in the research project "Mechanical Virtual Human of China", the results show that this software tool can help conveniently analyze the data collected by motion captured system.

Keywords: Virtual Reality, Human Skeleton Rigid Model, Measuring Rigid Body (MRB), Virtual Marker (VM), Motion Visualization.

1 Introduction

Human motion capture system has already widely used in research of human biomechanics. In key research project, Mechanical Virtual Human of China, supported by China National Natural & Science Foundation, motion capture system, Optotrak ™ Certus, is used to measure human body motion and results will be transformed into the motion of corresponding musculosketetal model, then human mechanics analysis can be made [1]. Dynamical visualization of captured data in 3D virtual environment will make researcher observe and analyze the acquisition data much more conveniently. The result of kinematics computation, dynamics computation and finite element computation could display in same virtual simulation environment, so the researcher can make full use of the captured data.

Visual3D™ is a commercial visualization software system for motion capture data [2]. It provides a convenient tool for analyzing the data in 3D visual environment, but it can't provide a fully 3D immersive and interactive environment. The emerging VR technology just can meet these challenges, which is a new-type human-machine

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interaction technology. Visualizing the motion captured system data with VR technology will make user observe and analyze the data more conveniently and intuitively.

The following chapters introduce the developed multi-functional visualization system for motion captured human body (KINE) which can not only visualize motion data, but also provide a set of interactive software tools to make data analysis and operation.

2 System Overview

The KINE system is composed of following main modules: data input interface, human skeleton modeling, motion reconstruction, and human-machine interaction, which is shown as Fig.1.

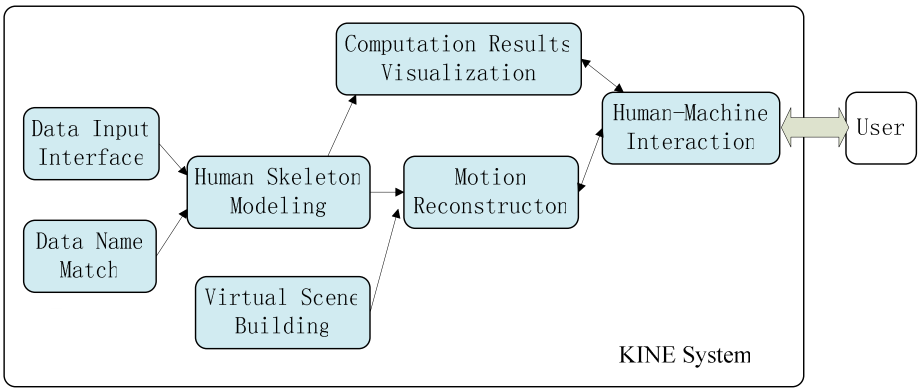

Fig. 1. KINE system structure

Human skeleton motion reconstruction is based on human multi Rigid Body Assumption (RBA) theory [3]. RBA is a widely used theory in human biomechanics research. It assumes that human limb is rigid body, which is linked by hinge, so the human body could be treated as a rigid body system without considering deformation under external force. The system provides a human skeleton modeling tool, which can build up human skeleton model automatically according to parameters defined by user.

The system provides standard data input interface which support C3D data format. The motion captured system uses high precise camera to detect motion trajectory of marker which is pasted on the skin of human body, and then transform into human motion data. In order to record whole human motion data, it is necessary to paste many markers on the measured human body based on the RBA theory. During the motion captured process, some pasted markers might not be detected by motion captured system because of blocking or out of measuring range, so make the captured data incomplete. This system provides customized interpolation method to fill blank data. There are linear, spine and customized methods for user's selection.

At the same time, the system is developed based on a software platform named VRFlier, which is a general development platform for Virtual Reality (VR) application. VRFlier is cross-platform, modular and extensible, which is developed by SJTU(Shanghai JiaoTong University) and has already supported successfully for many kinds and sizes of VR application development [4]. Based on VRFlier, KINE system has a VR-based human-machine interactive module; user could manipulate viewpoint and 3D model in an immersive stereo virtual environment.

3 Human Skeleton Modeling

According to human multi Rigid Body Assumption theory, human skeleton model has been built up, as following Fig.2 in which all the human body segment (e.g., thigh, upper arm and forearm) is treated as rigid body. In Fig.2, human body is composed of 15 rigid bodies whose names are listed in Appendix Table1. Each human limb is pasted a Measuring Rigid Body (MRB) and two Virtual Markers (VM). Each MRB is built up by 3 or 4 real markers, which could be detected by the motion capture system when the marker moves together with the human body. The posture of measuring rigid body is determined by MRB. The VM is not a real marker. It is only a marked point, which is fixed relative to the MRB. Its position can be computed through the posture of MRB. Through using MRB technique, the motion captured system could output the position data of the VM even if it is out of measuring range. With VM, it can not only decrease the measuring quantity of pasted real marker, but also improve the measuring accuracy.

The rigid body is linked through arthrosis, the midpoint between two virtual markers is thought as the center of arthrosis, but the shoulder and hip arthrosis are exceptional, their center is offset from corresponding virtual marker which is shown as blue and yellow points in Fig. 2. The length H and R is corresponding offset distance, which could be adjusted according to each measuring human body. Also, the geometry parameter of rigid body, such as length, center of gravid, inertia etc could be modified according to the captured human data.

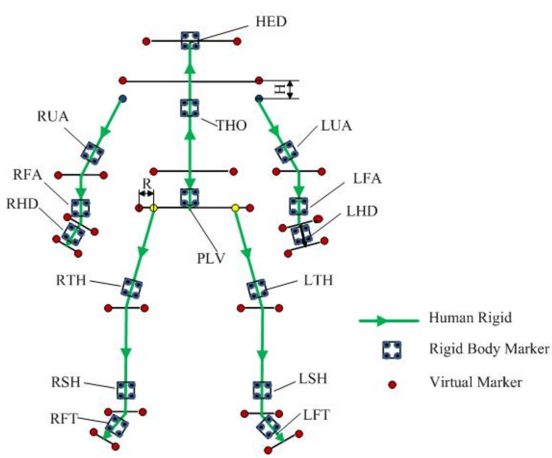

Fig. 2. Human skeleton rigid model

4 Multi-rigid Skeleton Model Motion Reconstruction

4.1 Coordination System Definition

Model-related computations are facilitated by associating a distinct coordinate system with each model segment. In KINE system, two kinds of coordination systems are used to describe the movement of human skeleton rigid model: World Coordination System (WCS) and Local Coordination System (LCS). The LCS move with respect to the WCS as the model segment itself moves. The WCS is determined by the motion captured system when it is initialized, the captured data is recorded under this coordination system. The LCS is determined by those four virtual markers located at the proximal and distal of each model segment. The proximal means that the two virtual markers are close to human rigid body THO (Truck, Refer to Appendix table1) and the distal is away from the THO. The definition of LCS is shown in Fig.3. The origin of LCS is located at C1 point, Z axis direction is from C1 to C2, Y axis is perpendicular to the plane determined by C2 and distal two virtual markers, and X axis is determined through right hand rule. The C1 and C2 is the midpoint of two virtual markers located at proximal and distal respectively.

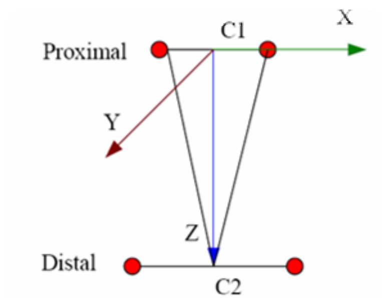

Fig. 3. LCS definition of model segment

Because of the exception of upper arm and thigh segments, the definition of these two segments' LCS is shown as following Fig. 4 and Fig. 5.

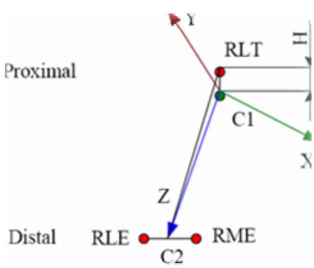

Fig. 4. LCS definition of Upper Arm

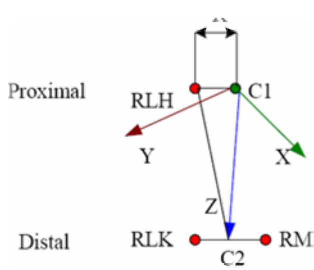

Fig. 5. LCS definition of thigh

4.2 Motion Reconstruction

Motion captured system uses video cameras or similar devices to track the instantaneous locations of target markers as they move. It is usually not possible to position the virtual markers at the proximal and distal segment endpoints, because these endpoints are defined to be at locations inside the body of the measuring subject. Because the position of VM is fixed relatively to MRB, we can compute the position of VM when MRB move along with the body segment. Each rigid body's position is invariable in LCS, so the rigid body's movement is the timing process of LCS.

The coordination system of 3D model in the virtual simulation environment might be different from the WCS. In order to make coordination transform conveniently in the 3D virtual environment, it is necessary to calibrate the rigid body. The calibration process is as follows: to move the proximal center of rigid body to the origin of WCS, and rotate the distal to Z axis. As shown in Fig. 6, the rigid body moves from P1 to P2. After the calibration, one can recording the rotation matrix M_{cali} which make the rigid body transform from P1 to P2.

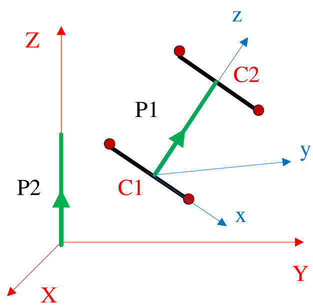

Fig. 6. Rigid body calibration

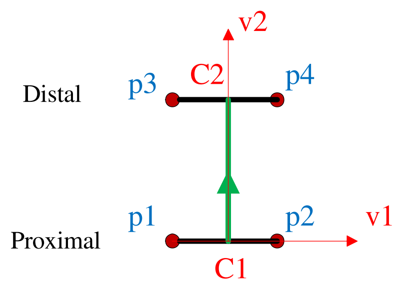

Fig. 7. Rigid body matrix transformation

In Fig. 7, the skeleton segment's posture is determined by the virtual markers (p1, p2, p3, p4), the vector $v1$, as following formula 1, determines the rotation matrix M_{rot1} along the z axis, and vector $v2$, as following formula 2, determines the rotation matrix M_{rot2} along the x axis and y axis. C1, as following formula 3, the midpoint of proximal end, determine the transformation matrix M_{trans}.

$$v1 = p2 - p1 \tag{1}$$

$$v2 = \frac{p4 + p3}{2} - \frac{p2 + p1}{2} \tag{2}$$

$$c1 = \frac{p2 + p1}{2} \tag{3}$$

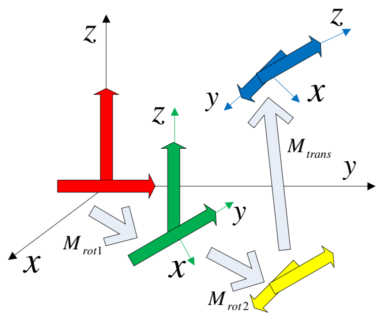

Fig. 8. Matrix transformation of rigid body in motion reconstruction

The transformation process of 3D rigid model in virtual environment is shown in Fig. 8. The center of proximal end is located at the origin of LCS, the distal is directed to Z axis when the rigid segment has been calibrated. The position of original 3D model is shown as red arrow. In there, the horizontal arrow denotes vector $v1$ and perpendicular arrow denotes vector $v2$.

Just as shown in Fig. 8, the transformation process is:

Firstly, rotate the rigid body segment along z axis using rotation matrix M_{rot1} to green position;

Then rotate the rigid body segment along x and y axis using rotation matrix M_{rot2} to yellow position;

Finally transfer the rigid body segment using transformation matrix M_{trans} to blue position, which is the final posture of the rigid body segment in this measuring frame.

So the transform matrix of rigid body:

$$M = M_{rot2} \times M_{rot1} \times M_{trans} \tag{4}$$

In Fig. 8, the center of vector $v1$ and $v2$ in green arrow is same as in red where offset a visual distance in order to describe the matrix transformation process.

5 System Integration and Application Verification

The KINE system is developed based on VRFlier platform using Visual Studio 2005. The system‘s human-machine interaction interface is shown as following Fig. 9. In this visualization example, the motion reconstruction data come from the research project of “Mechanical Virtual Human of China”.

Through KINE system, the user, with 3D stereo glass, could interact and observe the reconstruction process naturally and immersive. During the process of motion visualization, user could adjust the viewpoint and the motion replay speed in real-time through mouse, keyboard and other interface device. The system will also provide tools such as building up parametric rigid model, marker configuration, kinematics

Fig. 9. Human-machine interaction interface of KINE system

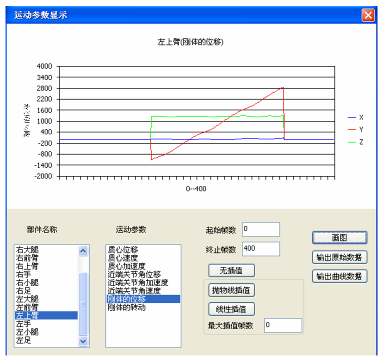

Fig. 10. Kinematics computation visualization of upper arm

and dynamics computation and visualization etc. KINE system also provide kinematics and dynamics computation function, the computation results can be visualized through graph and also can be output through data output interface. The following Fig. 10 shows the kinematics computation result of upper arm.

6 Conclusion

At present, the developed KINE system is being used in the research activities for "Mechanical Virtual Human of China". Dozens of kinds of human motion data including running, weight-lifting, riding bicycle etc have already visualized and tested by the system. The results showed that this system could satisfy researcher analyzing requirement of body motion captured data. It also has the flexibility to meet customized data formatting, processing, analyzing and reporting requirements.

Based on VR technology, the developed system provides a more interactive and immersive virtual environment for analyzing motion captured data. The best performance has obtained by the VR technology, which make the user observe and analysis the skeleton movement more naturally and conveniently. In the future, more functions will be added into this system.

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Appendix

Table 1. Name of human segment

Name	Human Segment
HED	Head
THO	Trunk
PLV	Pelvis
RTH	Right Thigh
RSH	Right Shank
RFT	Right Foot
LTH	Left Thigh
LSH	Left Shank
LFT	Left Foot
RUA	Right Upper Arm
RFA	Right Forearm
RHD	Right Hand
LUA	Left Upper Arm
LFA	Left Forearm
LHD	Left Hand