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Motion Deformation Style Control Technique for 3D Humanoid Character By Using MoCap Data

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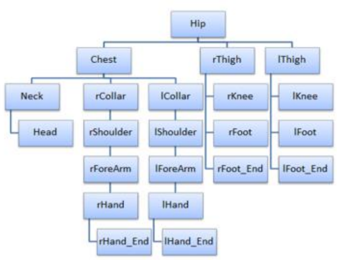
Graphical abstract



Abstract

Realistic humanoid 3D character movement is very important to apply in the computer games, movies, virtual reality and mixed reality environment. This paper presents a technique to deform motion style using Motion Capture (MoCap) data based on computer animation system. By using MoCap data, natural human action style could be deforming. However, the structure hierarchy of humanoid in MoCap Data is very complex. This method allows humanoid character to respond naturally based on user motion input. Unlike existing 3D humanoid character motion editor, our method produces realistic final result and simulates new dynamic humanoid motion style based on simple user interface control.

Keywords: Motion deformation, key pose control, 3D humanoid character

Abstrak

Pergerakan watak manusia 3D yang realistik sangat penting untuk diaplikasikan ke dalam persekitaran permainan komputer, filem, realiti maya dan realiti campuran. Karya in membentangkan mengenai satu teknik menghasilkan gaya pergerakan dengan menggunakan data penangkap gerakan berdasarkan sistem animasi komputer. Dengan menggunakan data penangkap gerakan, gaya pergerakan semulajadi dapat dihasilkan. Walaubagaimanapun, struktur susunan manusia di dalam data penangkap gerakan sangat merumitkan. Kaedah ini membenarkan watak manusia bertindakbalas semulajadi berdasarkan input pergerakan daripada pengguna. Tidak sepertimana Sistem pengubahsuaian pergerakan yang lain, kaedah kami menyediakan hasil akhir yang realistik dan menghasilkan gaya pergerakan dinamik yang baru berdasarkan kawalan antara muka pengguna yang mudah.

Kata kunci: Penghasil pergerakan, kawalan kunci pergerakan, watak manusia 3D

1.0 INTRODUCTION

Generally, four main techniques have been used to generate 3D humanoid character in computer animation; motion capture, keyframing, data-driven synthesis, and physical based approach. Nowadays, Motion Capture (MoCap) data widely used to create realistic 3D humanoid character motion. However, the movement from MoCap is not physically dynamic and it is difficult to reuse, and manipulate the motion style. Therefore it is difficult to satisfy dynamic and kinematics constraint in computer animation. A physics simulator need to update the state of a virtual environment, based on its current state, and external forces and torques. There are many kinds of physics simulation, depending on type of physics and the level of detail that is required for a specific application. In general there is a trade-off between accuracy and performance. We try to find the perfect balance between the trade-off.

3D humanoid avatar motion deformation process is very important part in the character animation. Currently, animation researchers try to control their 3D humanoid character's joints and make their character's motions look more realistic and resemble to the real human movement. Using motion capture technology, input data for character movement can be manipulated [1]. This research is going to present the latest method for simulating new dynamic humanoid motion style based on using MoCap data. According to the output result, we manage to satisfy the dynamic constraint and kinematics constraint such as fast walking, high jumping and high double spinning. From this research, the researcher can get a better understanding on what are the main issues and relevant techniques that are used by the recent researchers in this area.

Motion controller and simulator is the main part of our system to manipulate the 3D humanoid character motion. Motion controller act like a system brain which processes the player input and checked all the initial setup. The motion controller main task is to calculate the acceleration of joint angles based on the latest situation of the insert motion data has been generated. After that, the simulator will update the current state data through a process of dynamic simulation. Dynamic motion refers to the physical properties of 3D object, such as mass or inertia, and specifies how the external and internal forces interact with the object [2]. With the dynamic of character data, the control of the character's specific motion: walking, running, kicking, falling and jumping looks more realistic. We can calculate the angular acceleration of output and difference of initial angular acceleration from this structure. Motion simulator task is to display all action needed. It processes the MoCap data from motion controller into world space motion. All the information data from character as frames, character 3D character joints rotation and orientation will be manipulated. The motion editor control approach based on active dynamic control by normalizes the trajectory and change the states of vector space position in real time animation (Figure 1).

In our system, animator can produce new motion without changing the keyframes or re-capture the animation using motion capture. Using a single MoCap data, user can manipulate interactively the dynamic motion as requested. User can manipulate added forces to change from normal action to dynamic or superhuman action.

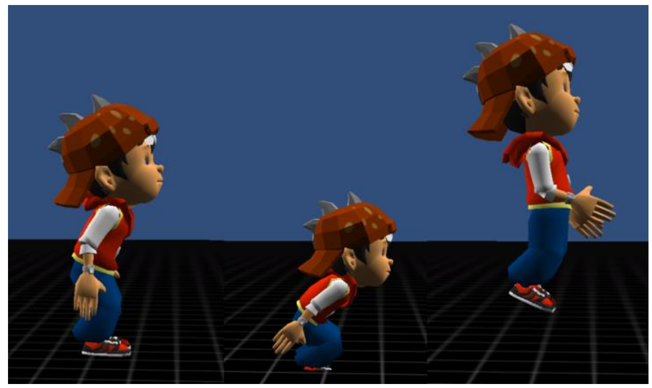


Figure 1 Initial and Final Motion State

2.0 RESEARCH BACKGROUND

Motion editing is very important in the computer animation for generate realistic 3D character movement. Currently, Kenwright [3] introduced a real-time modeling of 3D skeletal motion with balancing properties. They described an approach in modeling mid-to-lower body of 3D human movement in real-time. The dynamic motion in this research did not cover upper part of the body and human behavior interaction. Shapiro [4] focused on the "DANCE" platform for the development of physically based controllers for articulated figures. The main aim of this platform is to train an inexperienced user to develop dynamic controllers. They improved the motion editing technique by creating a toolkit for dynamic articulated humanoid characters controllers [5] under the physical simulation. The dynamic character controllers developed by using key-framed based control, reduced dimensionality physics, scripting controllers via a controller language, and interactive control of dynamic characters. However, this technique cannot perform a complete motion stage while interacting with the environment.

Dynamo [6] is a motion editing technique that allows a humanoid character to set and maintain poses robust to dynamic interactions. The system produces physically plausible transitions between motions without directly using a blending process. The main idea is to apply torques to match the desired world-space pose and maintain root orientation. After that, the motion blending emerges from continual simulation. The main weakness of this system is that it cannot collaborate with implausible situation such as displaying super-human abilities.

Zordan [7] worked on a new method that allows characters to respond to unexpected changes in the environment based on the specific dynamic effects. The system generates a physics-based response and takes advantage of the realistic movement that is achieved by an actuated dynamic model of motion capture process. The dynamic 3D humanoid character simulation responds to contact forces and determines the best plausible re-entry into motion library playback following the impact. To produce the results, a physically valid response will be created and the blending process will be generated into the desired transition-to motion. The dynamic motion controller will act in accordance with the upcoming motion. These techniques' main focus is to improve the character impact, but problems with responsive and interactive dynamic reaction for virtual human are still faced.

Abe and Popovic [8] study on a control algorithm that generates realistic animations by incorporating motion data into task execution. The system's focus is on interactive animation of dynamic manipulation tasks such as lifting, catching, and throwing. This interactive system allows Cartesian space force limits. The method always provides new command vectors that produce manipulation. This control algorithm has problems with the loss of control over some degrees of freedom. The motion stage will not be completed without pre-planning of the torques of motion. Allen [9] is another researcher who studies on 3D humanoid character motion editing. His approach focuses on timing constraints using a natural looking motion and allows a realistic response. However, the algorithm does not take into account subsequent effects for Parent-Childs concept using torques.

Muico [10] introduced a nonlinear control system using character contacts to edit motion-capture data. The framework uses nonlinear controllers with a large set of different styles of possible motions. The drawback of this control system is it cannot recover from larger changes in the environment because that requires intentional deviation from pre computed reference trajectories.

The ideas of this research compared to the previous research are the method calculates and changes the joints' speed and trajectory by adding external forces following Newton's law. The method is simple but quite effective. Using our techniques, animator can generate the dynamic motion inside the systems from a single MoCap data.

3.0 MOTION DEFORMATION

Generally, humanoid character motion development in computer animation involves joints of 3D models controlled by the skeleton hierarchy. The examples of our 3D humanoid character MoCap data hierarchy shows in Figure 2. These joints have been combined with three-dimensional geometric models, such as polygonal mesh. Animator need to generate realistic motion from this complex character hierarchy by control all this joints parameter [11].

This research will focus on the motion editing technique. Editing motion is a longstanding problem in computer graphics. Integrated framework needed to make a modification original data easily with physical quantities. A lot of technique [12] has been using before such as interpolation technique, motion displacement mapping, Force based motion technique, Momentum and linear relationship. This research focuses area on generate new motion style editing technique that involved the dynamic environment.

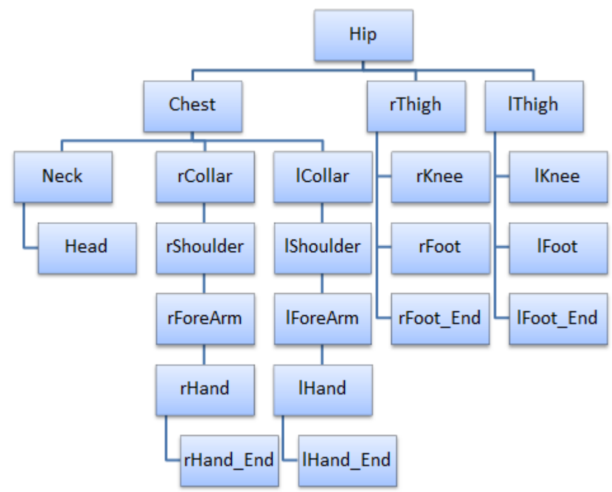


Figure 2 MoCap Data Hierarchy

3D humanoid character movement controlled using skeleton structure or hierarchy. A hierarchy uses grouping or parenting concept. For example, of human leg, the hip is the parent of the upper leg. Meanwhile, the lower leg is the child the upper leg, and the foot is the child of the lower leg. 3D character hierarchical model have smaller number of parameter that give consistency to dynamic motion. In real time animation environment, each bone depends on the orientation and the joint with its parent. 3D Character motion, m(t) can be derive as:

$$m(t) = (p_r(t), q_r(t), q_1(t) \cdots, q_n(t)) \quad (1)$$

Where $p_r(t)$ and $q_r(t)$ represent the position and the orientation of the root bone. The orientations of the rest of the n bone in hierarchy are $q_1(t)$ ....$q_n(t)$ refer to the coordinate systems of their parent at time. Generated motion has to enforce with physical law of motion for creating the realistic virtual human motion.

The function of inverse kinematics [13] is to calculate the bone's position, including the joints position and angles. Normally, inverse kinematics is used for motions involving the lower part of a 3D humanoid character's body such as joints from the foot to the pelvis [14-16]. It is very hard to use forward kinematics because the body position will be moving below the surface or ground. This transaction makes the character's motion very unreliable and unconvincing.

3.1 Controller Design

In this phase, the state of a rigid body is described using linear and angular velocity by calculates the joints' speed and trajectory. Change in linear and angular velocity depends on the total mass of an object, the location of the center of mass, and how the mass is distributed with respect to center of mass represented by an inertia tensor matrixs of freedom (DOF) and initial properties similar to human.

Although physic properties [17-18] can be applied to character motions in real time animation, however it is still limited when it comes to rigid objects. Our system focused on added forces to the 3D humanoid character motion while proportional-derivative controls maintain the trajectory balance in the vertical axis of motion.

In general, our system has two core parts: controller and simulator. Using controller function, we can calculate the angular joint acceleration directly by referring to the latest state of the motion capture data input. After that, the simulators update the process through dynamic character motion. From Euler angles equation, the orientation of the body frame is:

$$\theta = \theta_x i + \theta_y j + \theta_z k \qquad (2)$$

Where, Θx, Θy and Θz are scalars, and i, j and k are the world coordinate axes. From this equation, we calculate the angular velocity:

$$\omega = \frac{d\theta_x}{dt} i + \frac{d\theta_y}{dt} j + \frac{d\theta_z}{dt} k \qquad (3)$$

From this structure, we produce the output angular acceleration as the sum of $\ddot{\Theta}$initial and the difference of the angular acceleration $\Delta\ddot{\Theta}$. Meanwhile, the results input based on combination of a human body model and external physical input for the controller and the simulator. Our main structure combined the active control torque and other external physical interaction. The output motions have been generated by the physical simulator. Using this system, user can control the dynamic style simulation of character movement.

3.2 Integration Motion

Develop integration of motion data editing techniques and motion editor will be created based on articulated figures. Input from motion capture data will be modified such as a user-edited momentum profiles as well as other conventional constraints such as reference joints angles and body part position constraints, and calculates a new motion consistent with those components.

A lot of approaches have been developed for the purpose of character motion control based on dynamic [19]. Our new method can calculate and change the motion speed and trajectory using the proportional-derivative control. Our technique is creating motion using inverse kinematics method and produces a human walking motion using inverse dynamic.

3D humanoid character movement described by its mass, m, and its trajectory, r(t). We need to get positive gradient for increasing character velocity. Giving the time constraint in our calculation, the 3D humanoid character velocity is:

$$a(t) = \lim_{\Delta t \to 0} \frac{v(t+\Delta t) - v(t)}{\Delta t} = \dot{v}(t) \qquad (4)$$

So, the 3D humanoid character acceleration is defined as the limit change of velocity:

$$v(t) = \lim \Delta t \to 0 \frac{r(t+\Delta t) - r(t)}{\Delta t} = \dot{r}(t) \qquad (5)$$

We derive linear momentum, P, of 3D character defines using Newton's second law equations with forces, F has both magnitude and direction.

4.0 RESULTS AND DISCUSSION

Motion style need to be realistic and natural in computer animation. Figure 3 shows our system user interface. The system has a vertical trajectory control based on proportional-derivative method. The system can manipulate 3D humanoid character motion style such as jumping, front flip, running and walking. We can manipulate the original virtual human motion and change it to look more dynamic such as superhuman motion or less dynamic such as weaker movement than natural movement. The system user interface design is very simple and easy for student and beginner to use.

Figure 3 System User Simple Interface

We control the forward and backward speed by normalize the vector position to horizontal axis. The 3D character directions need to transform to world space relative to character orientation. Using speed level limiter, user can manipulate normal state of 3D humanoid motion of walking to fast walk or slow walk. For the vertical direction movement such as the flip motion, jumping motion and high kick, we control the force with increasing the velocity direction to vertical axis. If we constraints time with increased position, we can get faster vertical direction action refer to the root orientation and the maximum height. To generate the less dynamic motion style, we reduce the action force when the 3D character moves from the ground. This system also has mass manipulation by using different character mass with a same action force. If we reduce the character mass, we can get more dynamic action.

We edit the jumping motion by control root joint orientation and angular velocity around the vertical axis. We can manipulate the virtual human original jump motion from normal human jump to superhuman jump. This interactive editor can help animator to find the natural dynamic jumping that suitable with their 3D character. The connection between jump motion and external forces make the character movement look like a believable action.

5.0 CONCLUSION

Exploring the perfect balance between 3D humanoid character movement and interaction is the long standing problem [20-21] in computer animation. The main challenge for character motion in real time animation is to make the 3D humanoid character move automatically and instructed like real human. Researchers are trying to find a perfect balance between motion control and sophisticated long sequence interaction. Researchers need to control large data sets and automatic methods for mapping the correct input data into local models. Multiple learned models and different control methods need to be explored for the purpose of getting a natural, balanced dynamic character motion while maintaining the character's physical properties.

In this paper, we present a new technique for editing 3D humanoid character motion style with using MoCap data. Our system can calculate and change the motion speed and trajectory using the joints of skeleton. Our approach involves two main parts: motion controller as a brain and motion simulator as a motion processor. The system created show that it is possible to manipulate 3D humanoid character motion style and make it more interactive and dynamic. The main drawback of our system can manipulate the dynamic action but not a long sequence 3D humanoid movement. For future, researcher can add more complex deformation model and parameters that can generalize any action with simple parameter control.

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