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Dynamic Motion Control Editor for Virtual Human

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Abstract— Virtual human motion in computer games and animation look very dull and unrealistic. Researchers try to find a perfect balance to manipulate virtual human action in computer animation. Virtual human movement can be created by a combination of motions from different sources such as motion capture, manual keyframes, dynamic and kinematics simulation. This paper presents a new technique to edit virtual human action for dynamic motion control in the real time animation. Our approach allow user to manipulate trajectory of motion by controlling new additional forces and character mass that involves in virtual human motion for dynamic movement.

Index Terms— Motion control, virtual human, computer animation. virtual environment

1 Introduction

EDITING virtual human movement is the main issue in character animation topics. Usually, the virtual human action of in computer games is not smooth and unrealistic when compared with the movement of people resulting to the non-real-time animation as cartoons and movies. To achieve the natural motion in virtual human, a 3D character movement need to be edit so that a movement similar to real humans movement. Analysis of actual human movement data can be applied to characters in real time using motion capture technology. One of the new challenges in interactive computer games industry is to produce a dynamic character movement that can be manipulated as what animator wanted. This paper contributed a new technique to edit 3D character motion based on speed limit and character mass controller. From our system, new dynamic motion can be created from a normal movement while maintain the physical preferences details.

Our motion editor has two main part; motion controller and motion processor. The combination of this part can manipulate raw motion to get the new output dynamic movement for virtual human. Motion controller act like a system brain which processes the player input and checked all the initial setup. In general, dynamic motion control of the modification should have two main parts: the controller and the processor. 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 motion processor or simulator will update the current state data through a process of dynamic simulation. The result from this structure is the angular acceleration of output and difference of initial angular acceleration. Motion processor task is to display all action needed. It processes the motion data from motion controller into world space motion. All the information data from character as frames, character rotation and transformation will be manipulated. Our approach not focused on the motion only, m(t) but have control over the height and velocity of action with added external forces seen in the behavior.

In our motion editor, user can manipulate added forces to get new dynamic motion. For example, figure 1 show the different dynamic levels of jump motion refer to the original motion profile based on different speed in vertical axis. 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, kicking, falling and jumping looks more realistic.

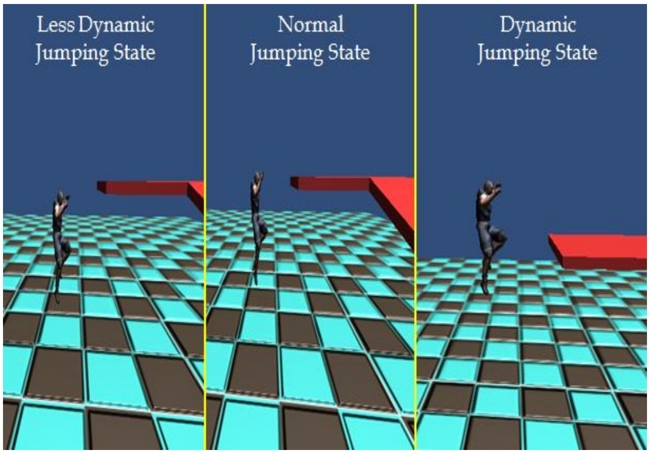

Fig. 1. Virtual human dynamic jumping.

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2 Related Work

Currently, one method for obtaining human movement data acquired using motion capture technology [2, 10, 14, 15, and 16]. Real human data can be apply to the animated virtual human in real time. However, the movement of people is very complex and unstructures [20].

It is difficult to identify the movement of people who differ from the physical aspect. Scale of the character mapping is very difficult to produce because the movement of animated characters in real time seems flawed and inconclusive. Current research in the field of computer animation is to produce a technique that can use the existing data on the movement in the different scenarios. Modification of the movement based on the physical effects [17] is the basis of the work to produce a dynamic response to the character movement. The main challenge in producing a dynamic response is the non-linear reaction is very sensitive to any movement of data. This is because the reaction momentum involving the synthesis of dynamic movement in the whole process.

According to Abe (2004) by using the optimum algorithm to convert the movement for the high dynamic response and can sustain nature of movement at the same time. There are three algorithms that should be considered the motion of pre-fitting, optimization, and Interpolation. All of these algorithms are essential to maintain the balance of nature and character dynamics reaction.

One of the related studies involves on how to modify and control the movement of the character when it comes to the internal forces of reaction. Active physical reaction generates the coordinate to control a movement [9]. Motion control systems in computer games should support the active role that may involve the manipulation of dynamic objects.

In recent years, researchers have been studying methods of modification and coordination of movements involving the synthesis of a physical reaction. This reaction sequence produces better natural movement. However, the complex character of the structure caused the reaction is very sensitive to the starting point of optimization. Therefore, this process cannot resolve problems in a realistic character. The physical restriction [7] has adapted the character on the linear momentum to sustain the reaction between the forces and moments involved.

From research based on [18] motion synthesis algorithms together with moments calculated from a single input data to produce realistic motion. Meanwhile, Dong Zhi (2007) using a physical model for the character-centered techniques for motion synthesis. Many approaches have been developed for the control of the dynamic alteration of the character movement. For example, using a model of muscle strength [16] the method of inverse kinematics, modify the path and speed of movement on muscle strength of the joints [17]. Another technique is to create motion using inverse kinematics and the result of human walking motion using inverse dynamics [18].

3 Skeleton Hierarchy

Development of virtual human movement in computer games involves joints of 3D models controlled by the skeleton hierarchy. These joints have been combined with three-dimensional geometric models, such as polygonal mesh. Animator try to make complex character movement by control all this joints parameter.

Currently, motion capture techniques have been used widely from video game animation to computer graphic effects in movies. An actor, are placed in a special suit containing sensors that record the motion to get the real human movement data. The motion data output is still not perfect because need to clean up from keyframes animator to make it look more natural [19]. However if we compare to other techniques, the output data from motion capture technology shows more realistic, convincing and better character movement than other techniques.

3D 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:

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

Where pr(t) and qr(t) represent the position and the orientation of the root bone. The orientations of the rest of the n bone in hierarchy are q1(t) ....qn(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 human character motion [20].

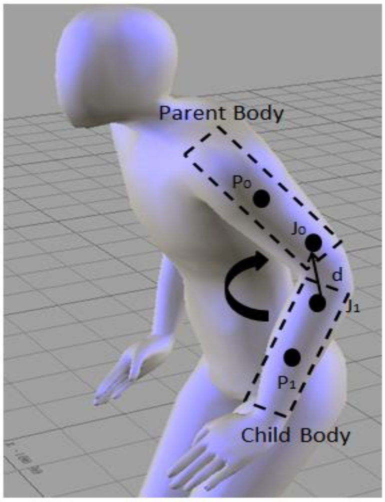

Fig. 2. Parent-child body relationship

Figure 2 shows parent body and required translation to the child body for 3D character. After transform the child body into global space, we can calculate the new position of the body. The parent body rotation matrix defined as R_0 and parent body position as $\vec{p}_0$. When the parent body move, automatically the child body transform from local body space to global space. The parent body position transformation:

$$\vec{p}'_o = R_0\vec{l} + \vec{p}_o \quad (2)$$

Meanwhile, the child body is defined as R_1 and $\vec{p}_1$. When the parent body moves, the joint J_0 and J_1 change to the same coordinate place. To transform child body from local space into global space:

$$\vec{j}'_n = R_n\vec{j}_n + \vec{p}_n \text{ , n=0,1} \quad (3)$$

To get the vector $\vec{d}$, we subtract $\vec{j}_o$ and $\vec{j}_1$. The new body position, $\vec{p}'_1$:

$$\vec{p}'_1 = \vec{p}_o + R_o\vec{j}_o - \vec{R}_1 j_1 \quad (4)$$

The function of inverse kinematics and forward kinematics is to calculate the bone's position, including the joints position and angles [6]. Normally, inverse kinematics is used for motions involving the lower part of a character's body such as joints from the foot to the pelvis [4,5,6]. 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.

In the case of shoulder rotation, or to get the position of the upper arm, we use forward kinematics calculation [6]. Forward kinematics is a top-down technique rotation used to position the character's upper body part in real time animation. Each skeleton joint has its local transformation, and parent transformation will determine the global transformation of each skeleton joint.

4 Motion Editor for Dynamic State

3D games character has a rigid body that has its own forces, velocity, mass and physical properties. The main step to control dynamic motion simulation is the basic dynamics of that character's movement.

Although physic properties 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 character motion while speed limitation to control motion height for vertical axis. From the velocity-time graph shows in figure 4, our character motion acceleration is increasing with the additional forces effect.

4.1 Main structure

In general, dynamic motion editor must have two core parts: controller and simulator. The structure of our system motion is shown in Figure 3. 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 [3], the orientation of the body frame is:

$$\theta = \theta_x i + \theta_y j + \theta_z k \quad (5)$$

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:

$$\omega = \frac{d\theta_x}{dt} i + \frac{d\theta_y}{dt} j + \frac{d\theta_z}{dt} k \quad (6)$$

The previous result from this structure is the output angular acceleration as the sum of Ӫinitial and the difference of the angular acceleration ΔӪ. 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 basic dynamic simulation of character movement. The methods linking the connection between forces acting to the body and acceleration can be categorized in two classes: maximal coordinate and reduced coordinate.

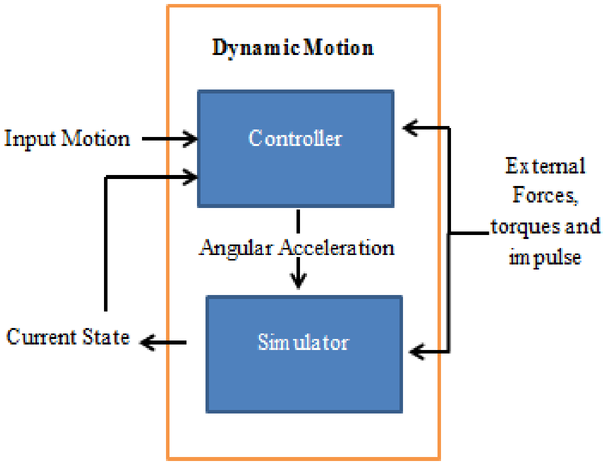

Fig. 3. Dynamic motion editor structure

4.2 Editing Forces

A lot of approaches have been developed for the purpose of character motion control based on dynamic. Our method can calculate and change the motion speed and trajectory using the joints of skeleton. Our technique is creating motion using inverse kinematics method and produces a human walking motion using inverse dynamic.

3D character movement described by its mass, m, and its trajectory, r(t) [3]. We need to get positive gradient for increasing character velocity as show in Figure 4. Giving the time constraint in our calculation, the character velocity is:

$$v(t) = \lim_{\Delta t \to 0} \frac{r(t+\Delta t) - r(t)}{\Delta t} = \dot{r}(t) \quad (7)$$

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

$$a(t) = \lim_{\Delta t \to 0} \frac{v(t+\Delta t) - v(t)}{\Delta t} = \dot{v}(t) \quad (8)$$

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

$$\mathrm{P} = mv \quad (9)$$

$$F(t) = \frac{dP(t)}{d(t)} = m\frac{dv(t)}{d(t)} = ma(t) \quad (10)$$

Using linear momentum, we calculate total external forces involves in character action:

$$\sum_i F_i(t) = m\sum_i a_i(t) \quad (11)$$

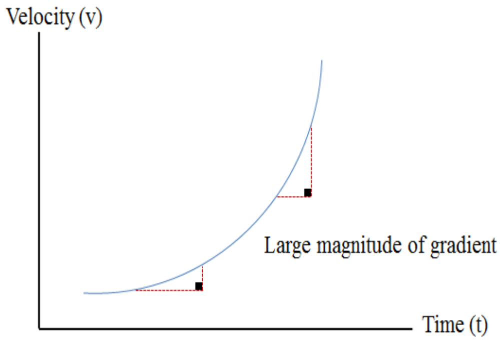

Fig. 4. Dynamic motion with high acceleration of virtual human speed

5 EXPERIMENTAL RESULTS

Our motion editor has a character mass control and speed limitation as the main interface. For example, Figure 6 shows the different of edited dynamic action using our motion editor. Our system can edit dynamic action such as jumping, front flip, falling and kicking. We can manipulate the original motion and change it to look more dynamic such as superhuman jump or less dynamic such as weaker jump than natural movement.

5.1 Basic Movement: Running and Walking

We control the forward and backward speed by normalize the vector position to horizontal axis. The character directions need to transform to world space relative to character orientation. Using speed limiter, user can manipulate normal state motion of walking to fast walk or slow walk.

5.2 Front Aerial Flip

We control the acrobatic speed with increasing the velocity direction to vertical axis as show in Figure 5. If we constraints time with increased position, we can get faster flip action refer to the root orientation and the maximum height of flip increasing. We can also make the action less dynamic by the limitation of the flip speed after character leave the ground. This system also has mass manipulation by using different character mass with a same action speed. If we reduce the character mass, we can get more dynamic action. The reactions from front flip motion show in figure 6(a).

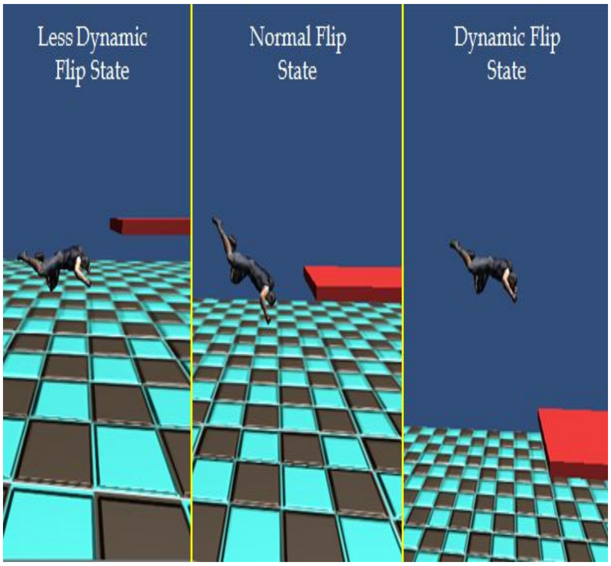

Fig. 5. Front flip action manipulation using motion editor

5.3 Level of jumping

We edit jumping motion by control root joint orientation and angular velocity around the vertical axis. We can manipulate the 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 interaction between jump motion and external forces make the character movement look like a believable action. For example, the levels of jumping motion show in figure 6(b).

6 Conclusion

In this paper, we present an algorithm for editing 3D character data with the speed and mass manipulation. Our system can calculate and change the motion speed and trajectory using the joints of skeleton. Our approach involves two main part: motion controller as a brain and motion simulator as a motion processor. The system created show that it is possible to manipulate 3D character motion and make it more interactive and dynamic.

Our system can manipulate the dynamic action but not a long sequence character movement. Exploring the perfect balance between motion editor for 3D character and object interaction still cannot achieve. The main challenge for character motion in real time animation is to make the character move automatically and instructed like real human. Multiple learned models and different control methods need to be explored for the purpose of getting a natural and balanced dynamic character motion while maintaining the character's physical properties. Editing and modifying techniques for motion capture animation data need to be maximized to the highest level to achieve realistic and convincing motions for 3D virtual characters.

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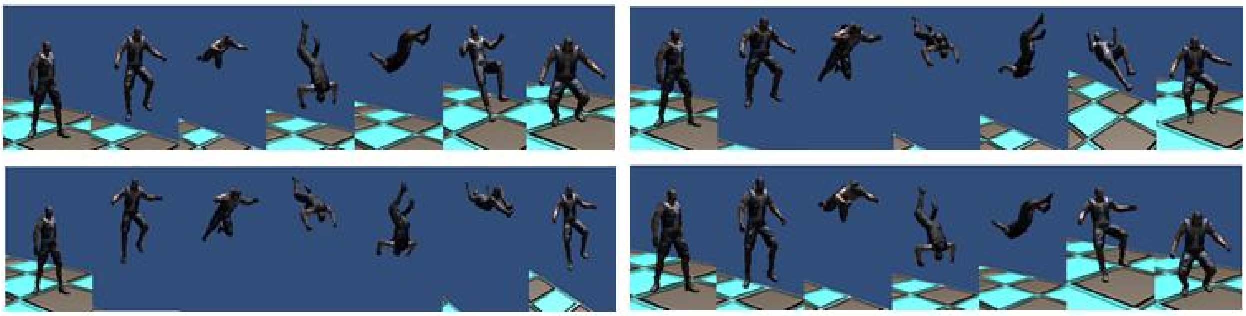
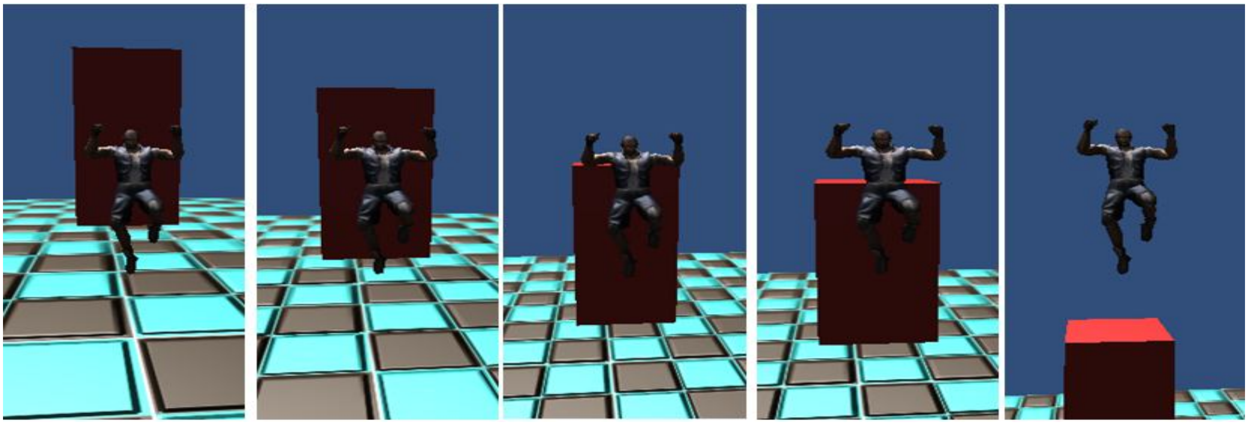
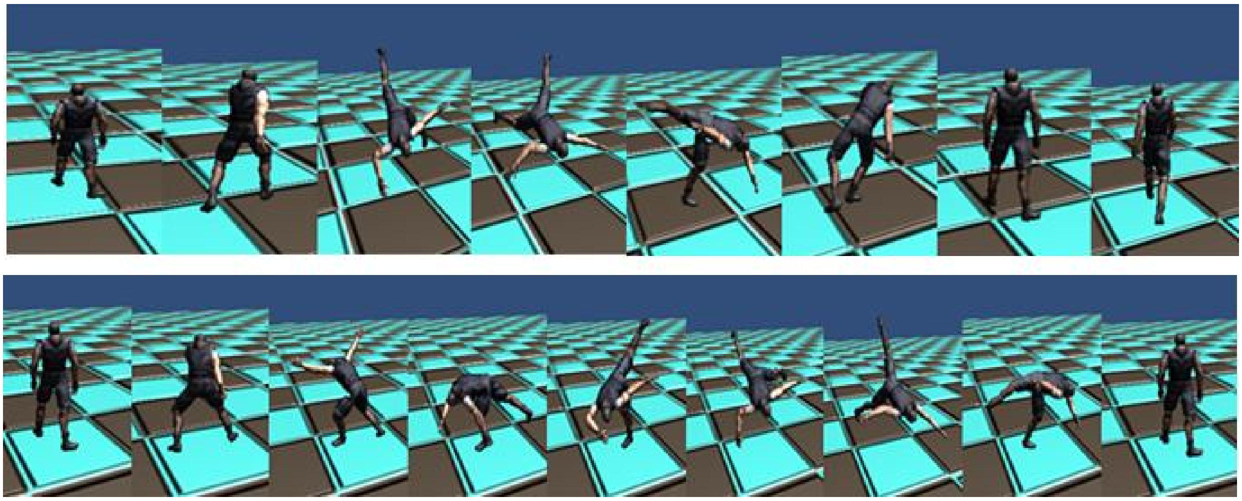


(a) Frontal Flip. (Left Top) The motion edited with decreasing additional force. (Right Top) Original frontal flip motion (Left Bottom) The motion edited with increasing additional force. (Right Bottom) The motion edited with additional mass and force



(b) Jumping State. Edited to make a lower and higher jump. The original motion shows in the middle image.



(c) Kick State. (Top) Original kick action. (Bottom) The motion edited with time and position constraints.

Fig. 6. Experimental result using motion editor for dynamic motion in virtual human