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Research on the Diving Simulation System on Three Dimensional Computer Animation

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Abstract

Three dimensional computer animation and motion simulation is an important means of technical analysis and diagnosis of sports training techniques. Springboard diving simulation system is researched in this paper by using three-dimensional computer assisted animation, and the human body model suitable of the system is established. Then we used free deformation method based on NURBS deformed to achieve the body's joint movement. Three-dimensional human body model and its motion model are established in the computer by introducing computational geometry. At last, the simulation system is realized by using OpenGL graphical programming interface, and the position difference simulation of the platform is carried out in the system. The visual effect and real-time motion of the human body model is performance good in this paper, and it has a high application value to the guiding practice.

Keywords: *three-dimensional animation, computer assisted, diving simulation system, human body model*

1. Introduction

The level of Chinese diving is very high, but the traditional training mode relies too much on experience. The application of scientific principle combined with appropriate technical means not only can tap the potential of the movement of athletes, which can improve the sports achievement, but also can make the athlete's training more scientific, more systematic, and reduce the culture period of the athletes, which prolong the service life in their sports career. The diving simulation system comes into being in this context, and many scholars have done some research on it. The human body modeling technology is an important technology in the simulation system. For many years in the past, three-dimensional human modeling and dynamic simulation has become an important research direction of computer graphics [1]. In technical analysis of diving, the use of a computer simulation model of the entire system can guide training more intuitive and efficient, which can make training more scientific and training effect better.

2. Application of Computational Geometry in Diving Simulation System

Diving simulation system on three-dimensional computer animation is relying on computational geometry. And computational geometry is mainly studied the surface information representation, approximation, analysis, splicing, deformation *etc.*, in the environment of computer image system. The following is a brief introduction of the basic knowledge of computational geometry which is introduced to establish the three-dimensional model of the human body.

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2.1. Computational Geometry Overview

The basic knowledge of computational geometry includes a lot of content, and taking the computational geometry used in the diving simulation system as an example, the basic overview is as follows.

(1) Common parameter curve

B-spline curve: The mathematical equation of K sub B-spline curve is as follows [3].

$$P(\mathrm{u}) = \sum_{i=0}^{n} d_i N_{i,\mathrm{k}}(\mathrm{u}), \qquad u_k \le u \le u_{n+1} \tag{0.1}$$

Where the data points d_i, $i = 0,1 \cdots n$ are called control vertices. The characteristic polygon of the curve is formed by n-k+1. $N_{i,k}(\mathrm{u})$ is called B-spline basis function (abbreviated as B-spline) which is determined by the node vector $U = [\mathrm{u}_0 \le \mathrm{u}_1 \le \cdots \le \mathrm{u}_{n+k+1}]$ forming from non decreasing sequence of the parameter u. B-spline basis functions can be calculated in accordance with de Boor-Cox recursive formula. The recurrence formula is as follows.

$$\begin{gathered} N_{i,0}(\mathrm{u}) = \begin{cases} 1 & u_i \le u \le u_{i+1} \\ 0 & others \end{cases} \\ N_{i,k} = \frac{u - u_i}{u_{i+k-1} - u_i} N_{i,k-1}(\mathrm{u}) + \frac{u_{i+k} - u}{u_{i+k} - u_{i+1}} N_{i+1,k-1}(\mathrm{u}) \end{gathered} \tag{0.2}$$

Where al zero denominator of all provisions of the term is zero.

B-spline basis function is completely determined classification by the node vector U, there are three kinds of node vector classifications: uniform, open uniform and non uniform. The distance from the two node value of the uniform node vector is constant, and the generated curve is called uniform B-spline, such as {0.0, 0.2, 0.4, 0.6, 0.8, 1.0}, {1, 2, 3, 4, 5, 6, 7, 8}. In addition to the node in both ends whose value is repeated d times, the distance from the two node value of the uniform node vector is uniform, and the generated curve is called open uniform B-spline, such as {0, 0, 1, 2, 3, 3}(d=2, n=3), {0, 0, 0, 0, 1, 2, 2, 2, 2}(d=4, n=4). The distance from the two node value of the non uniform node vector is arbitrary, and the generated curve is called non uniform B-spline, like {-1, 1, 5, 6, 9, 12}.

Non uniform B-spline curves provide more convenience in the control curve shape. Different distance obtained from the node vector can be achieved different blending functions in different shapes which can be used to adjust the shape of the curve. Uniform B-spline, however, has a periodic mixing function that given the values of n and d, all the mixed functions have the same shape. Each function is merely a result of the movement of the front function. In this paper, we have adopted a uniform B-spline form.

NURBS curve: B-spline curve does not accurately represent the conic parabola arc, so the non uniform rational B-spline mathematical method is proposed, called NURBS curve. The NURBS curve is defined by a number of piecewise rational B-spline functions [4]. Its form is as follows.

$$P(\mathrm{u}) = \sum_{i=0}^{n} w_i d_i N_{i,k}(\mathrm{u}) / \sum_{i=0}^{n} w_i N_{i,k}(\mathrm{u}) = \sum_{i=0}^{n} d_i R_{i,k}(\mathrm{u}) \tag{0.3}$$

Where d_i is characteristic polygon fixed position vector, $N_{i,k}(\mathrm{u})$ is K sub B-spline basis function. w_i is the corresponding control point of the power factor. Node vector in the formula is $U=\{\alpha,\cdots\alpha,u_{k+1},\cdots u_n,\beta,\cdots\beta\}$. While all vertices and weight factor except w_i is unchanged, the formula of $R_{i,k}(\mathrm{u})$ in Formula(0.3) is as follows.

$$R_{i,k}(u)=\begin{cases}\dfrac{N_{i,k}(u)}{\sum\limits_{i\neq j=0}^{n}w_jN_{j,k}(u)+N_{i,k}(u)} & (w_i=1)\\ \dfrac{w_iN_{i,k}(u)}{\sum\limits_{j=0}^{n}w_jN_{j,k}(u)} & (w_i\neq 0,1)\end{cases} \tag{0.4}$$

(2) Common parametric surface

B-spline surfaces: Based on the definition and nature of the uniform B-spline curves, we can obtain the B-spline surfaces [5], which is defined as follows formula.

$$S(u,v)=\sum_{i=0}^{n}\sum_{j=0}^{n}d_{ij}N_{i,k}(u)N_{i,j}(v),\qquad u,v\in(0,1) \tag{0.5}$$

The formula above written in matrix is shown in Equation(2.6).

$$S_{yz}(u,v)=U_kM_kd_{kl}M_L^TV_L^T\quad y\in[1:m+2-k],z\in[1:n+2-l],u,v\in[0,1] \tag{0.6}$$

Where y,z represent the number of u, v parameter direction of the surface sheet, d_{kl} is the control point number of one B-spline surface.

NURBS surfaces: NURBS surfaces can be obtained by non uniform rational B-splines curve as the same, and it is also composed of piecewise rational basis functions. Its define formula is as follows.

$$\begin{aligned}S(u,v)&=\sum_{i=0}^{n}\sum_{j=0}^{n}w_{ij}d_{ij}N_{i,k}(u)N_{i,j}(v)\Big/\sum_{i=0}^{n}\sum_{j=0}^{n}w_{ij}N_{i,k}(u)N_{i,j}(v)\\&=\sum_{i=0}^{n}\sum_{j=0}^{n}d_{ij}R_{i,\mathrm{j}}(u,v)\qquad u,v\in[0,1]\end{aligned} \tag{0.7}$$

Where $R_{i,j}(u,v)$ is piecewise rational basis function of NURBS surfaces.

The diving simulation system studied in this paper using the B-spline surface to simulate the surface of the human body model, and the movement of the human body is realized by the free deformation method based on the NURBS surface.

(3) Graph transformation

Graphic transformation is one of the basic contents of 3D computer animation modeling. By the transformation of the graph, the complex figure can be generated by simple graphics, and the 3D graphics can be represented by 2D graphics. By using the graph transformation, the model can be translated, rotated, scaled and rotated, and so on, and can be used to determine the position and orientation of the object model in the scene. Graphics transformation is very rich in content, and the simulation system used graphics geometric transformation and projection transformation in this paper. The following is the specific implementation of the transformation.

Geometric transformation of 3D graphics: The geometric transformation of the three dimensional pattern is based on the transformation of the point, and the coordinates of points are described by homogeneous coordinates. Suppose the coordinates of a point is $[x,y,z,1]$ before the transformation and is became $[x',y',z',1]$ after transformation. Geometric transformation matrix is needed in the process of transformation [7], and its representation form is as follows.

$$T_{3D} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$

The function of translation, scaling and rotation in the three dimensional space can be realized by multiplying the matrix of the transformation and the coordinate point.

Projection transformation: In order to get the perspective projection of the three-dimensional object, the point is transformed along the convergence to the projection reference point. Assuming the projection reference point at the position zppr along the zv axis, and set the observation plane at zvp, as shown in Figure 2-1. We can write the parametric equation of the point on the description of the perspective projection line.

$$\begin{cases} x' = x - xu \\ y' = y - yu \\ z' = z - (\mathrm{z} - \mathrm{zppr})\,\mathrm{u} \end{cases} \tag{0.8}$$

Where parameter u is from 0 to 1, and the coordinate position (x', y', z') represents a point in the projection line.

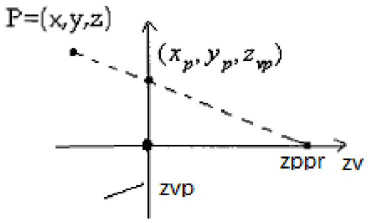

Figure 2-1. Point P to Perspective Projection on the Observation Plane

2.2. The Three-Dimensional Human Body Model

Three dimensional modeling technique is a technique to generate and process 3D data by computer. In this paper, a 3D modeling technique is used to build a human body model. At present, the research of modeling technology mainly has the following three aspects [8].

(1) Problem of shape

The establishment of three-dimensional model of the object, need to enter the 3D data to the computer, and in the practical application, the input of three-dimensional data is a complex problem. For some certain specific applications, it can enter the coordinates of some control points by digitizer, and then established the model by surface and curve fitting method. And we can also use the method of two-dimensional image reconstruction to establish the three-dimensional model.

(2) Problem of Fidelity

In order to improve the reality, people begin to consider the complexity of the light source. For realistic display of the most powerful way - ray tracing method, researchers are also focusing on the research, and the main focus is how to improve the speed of ray tracing algorithm.

(3) Problem of speed

The biggest obstacle to the application of 3D realistic graphics is that the calculate speed is very slow. Generally speaking, the higher the requirements of graphic fidelity, the greater the amount of computation, and the slower the calculate speed. At present, the researchers improve the speed from the two aspects of software and hardware. In addition, in the process of graphics modeling, the speed of graphics processing can be improved by taking the corresponding modeling method according to the specific problems.

Due to the limitation of the condition, we adopt a method to reconstruct the 3D value point from 2D figure. In this method, the human body surface is divided into several parts, and each part is divided into an irregular grid structured, which is described by a series of type value lattice. However, due to the complexity of the structure of the human body, it makes some errors in some places, such as where the arms and body contact the inside of the thigh and the lower leg, etc. The points of these places have been measured for many times and calculated by using the three Lagrange function for interpolation, and get a better effect.

3. Research on Modeling Motion Control in the Simulation System of Diving

The key technology of the simulation system is the establishment of the motion control model in the process of human body diving. Three-dimensional computer animation, according to the formation of the diving movement, can be divided into key frame animation and algorithm animation. The key frame animation is based on the picture which the traditional animation designers provide, so that the computer automatically generated in the middle of the image. Algorithm animation is also called program animation, and the animation of the role is described by the role of the algorithm. The algorithm applies the laws of physics to the parameters. For example, the motion of the object follows the law of kinematics, and the change of the initial motion, the stop motion and the velocity of the object follow the law of dynamics. Therefore, the algorithm can also be divided into animation algorithm animation and animation algorithm animation [9]. In this paper, the trajectory of human motion used in the simulation system of springboard diving does not consider the dynamic factors, and only simulate from the point of view of kinematics. Therefore, it should belong to the kinematics algorithm animation.

3.1. Springboard Diving Model

The springboard diving refers to that athlete dives on the springboard which one end of the diving board is fixed and the other is elastic. According to the height of the springboard from the water, there are 1 meters and 3 meters board. Springboard diving action consists of four parts: running board, take-off, air movement and into the water. The take-off technology is the most difficult to grasp, and is the most critical and basic technology. It requires a stable, accurate and high jump. Take off technology has a direct impact on the air movement and the water effect, and affects the quality of the completion of the action.

The take-off of a diving board is made up of two technical actions: step of one foot jump and press the jump feet together. The two technical movements are accomplished by the lower pressure and rebound of the diving board and the regulation of the body's muscles.

Through the research of the diving platform, the four rigid body model is established, which is consistent with the actual person-board system, as shown in Figure 3-1.

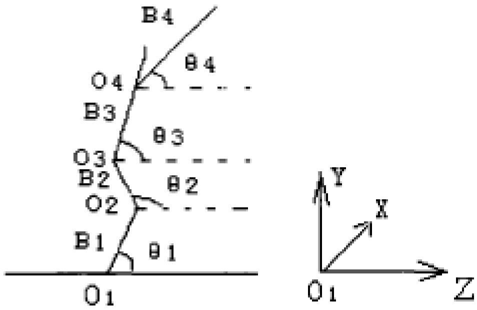

Figure 3-1. Four Rigid Body Model of Human Body

In figure above, O1 is the origin of coordinates, and also the contact point of the athlete foot and the board when the board is level. Bi (i=1,2,3,4), represented the i of a rigid body, is used to simulate the body's calf, thigh, upper body and arm respectively. Oi is the each part of the connection point, and simulate the ankle, knee, hip and shoulder joints respectively.

If we regard the springboard as an elastic flat plate in the plane, its force diagram is as shown in Figure 3-2.

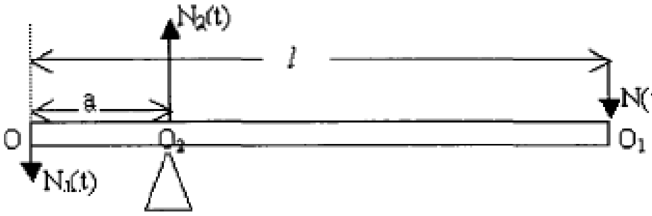

Figure 3-2. Force Diagram of Springboard

There is a pivot point in the middle of the board, and the adjustment of the pivot point can effectively change the length of the board to change its vibration period. Assuming that the human body mass is m, and the mass of the springboard is $\tilde{m}$, and the length is l. The distance from the pivot point to the fixed end is a, and the force of the human body on the springboard is N(t). and the acting force at the pivot point is N2(t), and the acting force on the fixed end of the diving board is N1(t). The kinetic equations that satisfy the human body and the diving board are as follows.

$$\begin{cases} N(t) - \sum_{i=0}^{4} m_i g - \sum_{i=0}^{4} m_i \ddot{y}_i(t) = 0 \\ N(t) + K y_{o1}(t) + \tilde{m} \ddot{y}_{o1}(t) = 0 \end{cases} \tag{0.9}$$

Where $y_i(t)$ is the position of the centroid of the rigid body in the section i of time t. $y_{o1}(t)$ is the position of free end of springboard of time t. K is a constant that is determined by the intrinsic parameters of the board.

In the springboard diving competition, the judges score a athlete mainly based on the air action and the effect of into water, especially the into water effect giving the impression is very deep. However, to complete the action in the air and good effect of into water, the athlete must have plenty of air time, which is, have enough flight height, and the height of the human body from the springboard to take off, directly controlled by the human body from the moment of the centroid velocity [10].

3.2. Human Body Motion Model

To study the human body motion model, we must first set up the human body coordinate system. In this paper, we take the middle point of human connection heel as origin of coordinate system. The X axis is the left side of the body, the Y axis is the height side of the body, and the Z axis is the direction of the plate. The body model coordinate system is as shown in Figure 3-3.

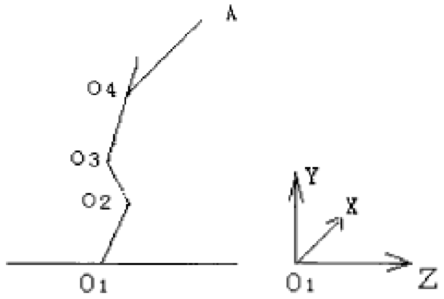

Figure 3-3. Human Body Model Coordinate System

We use the angle between the four rigid bodies and the horizontal plane to establish the kinematics equation on the basis of the human body model coordinate system, to control the motion of the human body. To a certain limb, assuming that it rotates alpha, beta, and gamma angle around the local coordinate system in itself of the X axis, Y axis and Z axis, and then translates x, y, z along the coordinate system. We can use the transform matrix to calculate the result. Assume that $R_x(\alpha), R_y(\beta), R_z(\gamma)$ are the rotation matrixes which rotate alpha, beta, and gamma around the coordinate system of the X axis, Y axis and Z axis. T (x, y, z) is a translation transformation matrix with respect to its own coordinate system. The transformation between the two adjacent limbs can be expressed as follows [11].

$$M = R_x(\alpha)R_y(\beta)R_z(\gamma)T(x, y, z)$$
(0.10)

The coordinate value of point A with respect to the global coordinate system is as follows.

$$(x'_A, y'_A, z'_A) = (x_A, y_A, z_A)M_A$$
(0.11)

Human motion simulation can be carried out with the human body kinematics model. In this paper, the free deformation method based on NURBS is used to realize the bending deformation of the joint. The method is simple and intuitive, and it can achieve a better effect.

4. Realization of Diving Simulation System by OpenGL

The diving simulation system can be achieved by OpenGL graphics technology with 3D human body model, springboard diving model and human body motion model, in the computer animation assisted. The process of three-dimensional animation simulation of OpenGL in the computer is as shown in Figure 4-1.

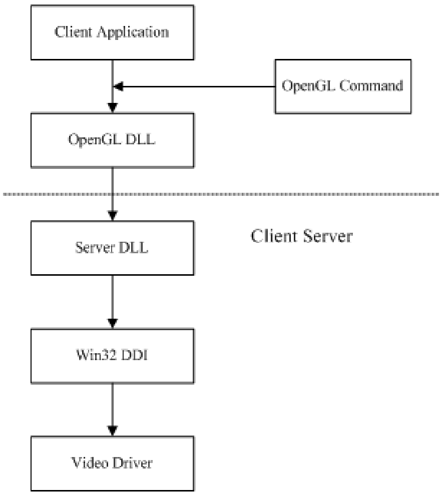

Figure 4-1. The Process of Three-Dimensional Computer Animation

We abstract the whole process of springboard diving, using the design idea of object oriented programming. According to the function of each part and the relation between each part, we separated them and establish the corresponding class for each object. In the simulation system of human-board, we mainly establish the following several classes: Human body model class CAtheleteDlg, Springboard model class CSBParamDlg, Speed setting class CSuduDlg, Zoom set class CScaelDlg, Curve output class CCuvre, Animation demo class CBody, Computing calculate class CJiusna, Optimization class COPtimization, View class CProgramView. Each class has its own specific functions, and can be achieved independently, and there is a certain level of logic between the various classes. The general relationship between the various classes is as shown in Figure 4-2.

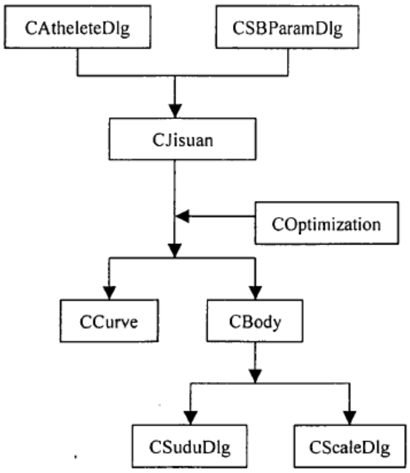

Figure 4-2. The Logical Relations between the Various Classes

The diving simulation system on three-dimensional computer animation aided is achieved through programming on the design of each class. Simulation experiment is carried out in the simulation system. In the process of running board and take-off, the athlete is walking, running, jumping and other movements in the springboard most of the time. Therefore, measured diving boards and quality block composed of human-board system's natural frequency in the simulation system with a quality block in the different positions. We chose 12 locations of 6cm, 16cm, 26cm, 36cm, 46cm, 56cm, 66cm, 76cm, 86cm, 96cm, 106cm and 116cm in the test. Then we processed the obtained data by the least square method. Table 4-1, lists the natural frequency of the diving board the 10kg block at different locations.

Table 4-1. The Data the Block at Different Locations

Position x(m)	Measured frequency(hz)	Calculated frequency(hz)	Absolute error (hz)	Percentage error (hz)
0.06	2.4144	2.4774	-0.0360	-1.45
0.16	2.5635	2.5393	0.0242	0. 95
0.26	2.5635	2.6012	-0.0377	-1.45
0.36	2.6855	2.6631	0.0224	0. 84
0.46	2.7466	2.7250	0.0216	0. 79
0.56	2.8076	2.7869	0.0207	0. 74
0.66	2.8687	2.8487	0.0200	0. 70
0.76	2.9297	2.9106	0.0191	0. 66
0.86	2.9297	2.9725	-0.0428	-1.44
0.96	3.0518	3.0344	0.0174	0. 57
1.06	3.0518	3.0963	-0.0445	-1.44
1.16	3.1738	3.1582	0.0156	0. 49
Maximal value			-0.0445	-1.45

It can be seen from the results of the table that the natural frequency of the different position of the same athlete on the springboard is more ideal compared with the natural frequency of the different position of the springboard.

We can also carry on the simulation of the different pivot point of the springboard, the difference of the quality of the athletes, the analysis of the take-off process and so on through the diving simulation system.

5. Conclusion

The traditional training is paid too much attention on the experience of coaches, but the skill of running board and take-off has poor training effect and the athlete's training time is too long. The diving simulation system on three-dimensional computer animation aided designed in this paper; establish the model of athlete diving based on the principle of computational geometry. We can find out the best diving track through the analysis of the athlete take-off position of the springboard in the training course, and improve the process of learning the athlete movement pattern board, so as to achieve the purpose of improving the training effect and the efficiency.

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