Taekwondo Action Design Combining CAD and Virtual Reality Technology

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Abstract. The current virtual reality modeling methods based on CAD models have too many model patches, long and ill-conditioned triangles. Therefore, it is difficult to meet the real-time rendering and visual requirements of the virtual reality system. This subject proposes a method of simplification and conversion of CAD models and applying them to virtual systems. First, the existing CAD models are exported to an intermediate format and analyzed to obtain mesh data, and then a new classification-based adaptive simplification is used. The algorithm performs multi-resolution simplification on the grid, that is, first classifies the grid according to the characteristics of the grid model, and then performs targeted simplification on the basis of the classification. This article mainly uses the kinematics method to analyze the technical movements of the cross kick, supplemented by the analysis of the dynamics. Through a comprehensive analysis of the data of the horizontal kick technique, the internal laws of the Taekwondo horizontal kick technique are explored from multiple angles, which provides a reference for improving technique, guiding teaching and training. The research results of this paper show that the correct working sequence of muscles is an important condition for improving muscle work efficiency, and it is also an important guarantee for improving link speed. The muscles of each link should work in the order of large and small, and the angle of each link should be within a reasonable range. The waist and hips are the hinge between the upper and lower limbs. The two swings of the upper limbs and the cross changes of the legs are inseparable from the waist and hips.

Keywords: Taekwondo action; virtual reality; CAD; model grid information extraction
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1 INTRODUCTION

Creative design needs to give play to people's creative thinking ability and create design schemes that did not exist before [1]. This work should generally be done by people. Non-creative work is some tedious and repetitive calculation analysis and information retrieval, which can be done with the help of computers. A good computer-aided design system can not only give full play to the creative role of people, but also make full use of the high-speed analysis and calculation capabilities of computers, that is, to find the best combination of people and computers [2].

With the gradual enhancement of computer graphics technology and network technology, virtual reality technology has become a more popular research field at home and abroad in recent years [3]. Virtual reality is through the construction of three-dimensional dynamic real scenes, so that users have real feelings and immersed in it, giving people an immersive sense of reality. The basis for the application of virtual reality technology in various industries must be to build a realistic, real-time three-dimensional virtual environment to reproduce the real environment. The research on character design and scene realization in virtual reality is one of the underlying core technologies of virtual reality technology. It is the foundation and guarantee for the application of virtual reality technology. The key to its status is beyond doubt. In the current 360-degree panoramic map, although the viewing angle is 360-degree up, down, left, and right, the browsing location is not continuous, which reduces the user's sense of experience and lacks a true three-dimensional scene. At the same time, there are many ways to implement 3D modeling. In addition to the commonly used 3D animation rendering and production software 3ds Max, Maya and other methods, there are also methods that convert a series of photos or scan data into high-resolution 3D mesh models [4].

After obtaining the VRML neutral file through the CAD data conversion interface, this paper analyzes the specific grid model data reading and analysis methods of the VRML neutral file. From the perspective of virtual reality modeling, based on the requirements of visual modeling, combining our existing conditions and some existing development tools, we have developed an OpenFlight that can quickly generate virtual reality visual requirements based on existing product CAD models. The system is implemented by programming with C++, OpenGL and OpenFlight API under the VC platform. Tests in a virtual environment have verified that the model can better meet the real-time rendering requirements, and the visual effects are more reasonable. The two arm swings of the upper limbs are the basis for the second force exertion of the hips. Two swing arms transfer the moment of inertia of the upper arm to the offensive leg by twisting the waist (torso). The reasonable rotation range and timing of the waist organically link the rotation of the upper and lower limbs, which can significantly increase the attacking effect of the offensive leg. The shoulder muscle contraction drives the upper arm to swing, and the back waist muscle contraction, drives the thighs through the hips, and the thighs drive the calves and even the toes. Therefore, training the swing amplitude and strength of the upper limbs, and coordinating the working timing of the upper limbs, trunk and offensive leg muscles and the amplitude of the link rotation are of great help to improve the attacking effect of the offensive leg.

2 RELATED WORK

The geometric model is an important part of the CAD/CAM system. As we all know, to solve a problem with the help of a computer, we must first establish an appropriate model. In the application of CAD/CAM, specific engineering operations are often carried out on the basis of geometric models. In the entire product design and manufacturing process, the technologies of shape design, engineering analysis, process design, and numerical control programming are all related to geometric models, which provide basic information for design, analysis, calculation, and manufacturing. Arandjelović [5] pointed out that geometric models are tools for describing and recording the geometric shapes of design objects within the CAD/CAM system. CAD/CAM users do not directly touch these models, but work through appropriate design commands. In terms of

software, an image-based 3D reconstruction is used to generate a 3D model of an object from a photo, which is part of the image rendering. Research in this area is gradually deepening, but it has not yet reached a practical level. The other is based on model conversion, which converts existing engineering models, such as CAD three-dimensional modeling, architectural planning renderings, etc., into virtual reality visual models. Automatic modeling is simple and convenient, saves time, and does not need to purchase a commercial model database, and saves costs. It should be a key research modeling method. Wei et al. [6] pointed out that the Precision and Intelligent Laboratory of Tokyo Institute of Technology has researched a humanized interface for building 3D models—SpmAR; INEC has developed a virtual reality system to process 3D body models in CAD. The University of Tokyo has made certain breakthroughs in remote control. Kittel et al. [7] have formulated relevant strategies for research in the field of virtual reality technology. The establishment of virtual environment, the research and application of virtual reality, and the development of virtual scene model distributed system are developing in the direction of depth. Nowadays, it has listed the research on virtual reality technology as a national key project. Many domestic research institutions and universities have also actively invested in the research field of virtual reality technology and have achieved certain research results.

Bird [8] believed that in the mobile Internet era, real-time rendering of 3D graphics on the PC and mobile terminals has become the core of the virtual reality application experience. Wood et al. [9] pointed out that for the modeling of characters and scenes in virtual scenes, the more refined the model is, the higher the rendering quality of 3D graphics, and users will naturally have a stronger sense of reality. However, the more refined the model, the greater the amount of data in points, lines, and areas, and the greater the system memory overhead. The 3D graphics rendering speed becomes the shortcoming of the virtual scene system, which seriously affects the display of 3D graphics. Speed cannot better meet the user's objective requirements for the real-time performance of the virtual scene system; on the contrary, if you blindly pursue real-time and 3D graphics rendering speed, the real-time performance of the virtual scene will be guaranteed, but it must be at the expense of the accuracy of the 3D model. This will seriously affect the user's authentic experience and violate the immersive purpose of virtual reality technology. Monks et al. [10] believe that the authenticity and real-time issues of virtual scenes conflict with each other, forming the so-called contradictory issue. How to balance the three-dimensional graphics drawing speed and drawing quality has become a big problem.

3 EXTRACTION AND DESIGN OF GRID INFORMATION OF TAEKWONDO ACTION MODEL UNDER THE INTEGRATION OF CAD AND VR TECHNOLOGY

3.1 Virtual Reality Modeling

Virtual Reality Modeling Language (VRML) is a standard for describing scenes in virtual environments, which can be used to establish an interactive three-dimensional virtual reality environment on the Internet. VRML has basic features such as distributed, interactive, platform-independent, three-dimensional scenes, multimedia integration, and lifelike nature.

In addition to the transform, shape, appearance, and material nodes in the VRML format files generated from CAD software, the involved nodes include IndexedFaceSet nodes, Coordinate nodes, Normal nodes, etc. A series of shape nodes with IndexedFaceSet node as the value of the geometry field. The VRML node group involved in displaying the geometric model of the part and the relationship between these nodes are shown in Figure 1.
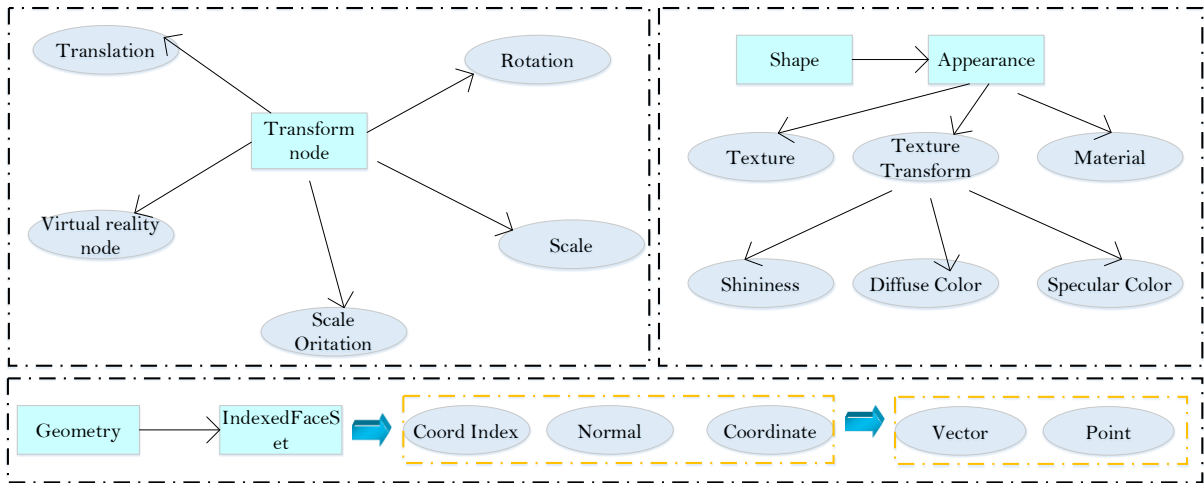
Figure 1: The nodes of the virtual reality model generated in the CAD software and the relationship between the nodes.

In order to make the virtual space dynamic and convenient for user interaction, VRML provides the definition and use of events and routes. Nodes can be changed by receiving events. By receiving eventIns instructions, nodes can change their current state. When a node is changed, it will change the state of the change. Reflect, send some events (eventOuts). The function of route is to connect the events of nodes, create a path (route) between two nodes, and make one node control the state of another node by sending events.

3.2   Analysis of Model Mesh Files

In this article, a CFileParse class is defined to implement file parsing. First, we define a file stream, read the contents of the file into the singlerow character array through the fgetc method, and then parse the strings in the array until the traversal is obtained Information about all the faces and vertices in the model. In the VRML file, the IndexFaceSet node is applied to face geometry modeling, and a face set is used to describe a surface of the geometric model. Here, the face set is composed of a series of adjacent triangular faces. The coordinates are described by the three-dimensional point column of the child node Coordinate, that is, the coordinate information of each vertex contained in the surface is read from "point[" until the end of "]". The index value of the vertex of each triangle contained in this face in the point column, the interval between each triangle is -1, so when reading the VRML file, every time it encounters "-1". After reading all the triangular faces in the face, it has a face set for this face; the normal node lists the normals of the coordinate vertices used to construct all the triangular faces in the face set. The normal direction of each triangle and the order of the corresponding vertices conform to the right-hand rule, that is, bend the fingers of the right hand in the order listed in the coordIndex of the triangle, and the direction the thumb points to is the normal direction of the triangle. If the ccw field of is set to FALSE (the default value is TRUE), the normal direction of all triangles in the node will be reversed.

The IndexedLineSet node represents a 3D shape formed by a series of line segments of a set of specified vertex components. Similar to the IndexFaceSet node, the coordinates of the vertices in the IndexedLineSet node are also described by the three-dimensional point column of the child node. The index value in the coordIndex field indicates how to connect the vertices to form a line segment. In the grid file, the index value of the coordIndex field is linear. Sorted in ascending order, therefore, this article does not recommend extracting the information in the coordIndex

field. However, for more complex parts, the node information obtained by analysis has to undergo further coordinate transformation, including coordinate scaling, rotation, and translation. In VRML, the transform node is a basic structure. It is a common grouping node, which can be used as a container for many objects. However, transform node provides more powerful functions. We analyze the grid file step by step. After successfully reading all the line, surface nodes and related normals and other information, we store it in the corresponding data structure, and finally determine the relationship between the downline and the points on the surface.

3.3 Design of Data Structure

The objects drawn by CAD software are described by points, lines, and surfaces in the mesh file. Each mesh model is composed of a series of surfaces of the same type. The lines are connected, and each face is composed of a series of adjacent triangles. Therefore, according to the object-oriented thinking, this paper designs the model, face, line, triangle, and node respectively. We create a Lines field to mark the correspondence between the surface and the boundary line. In order to realize the simplification and restoration of the model, a more reasonable data structure is needed to store the relevant information in the model, such as the information of the vertex coordinates, the index information of the vertices of each triangle face in the point column. The MyDataType class is a data structure specifically used to store this information. Figure 2 shows the data structure of Taekwondo action design combining CAD and virtual reality technology.
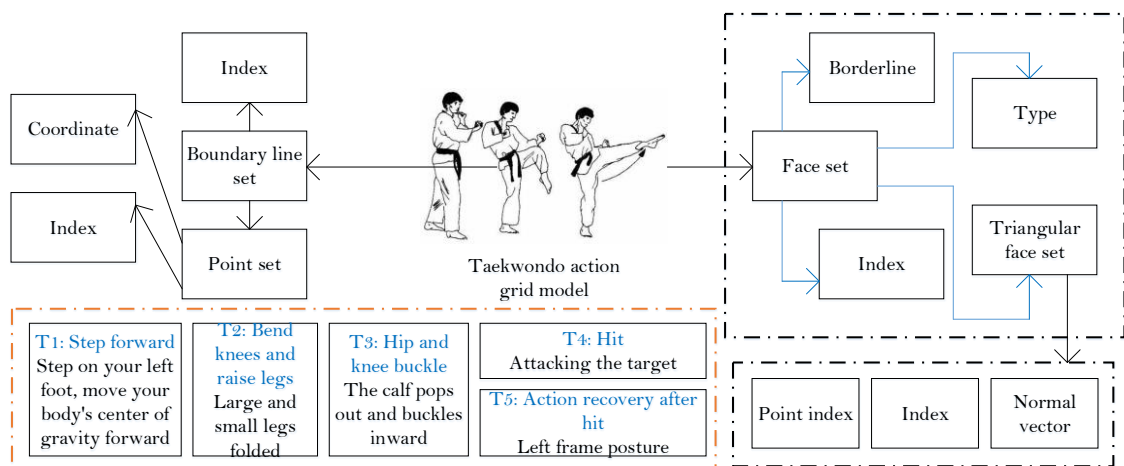
Figure 2: Data structure of Taekwondo action design combined with CAD and virtual reality technology.

3.4 Model Occlusion and Blanking Processing

For complex assembly parts, occlusion and blanking are important model reduction methods, because as far as assembly parts are concerned, the assembly relationship between components makes a large number of visible surfaces become internal invisible face sets. The sub-faces can significantly reduce the burden of drawing in real-time systems.

When the line-of-sight equation is determined, we sort the distances from the intersection point to the point of view of the triangular facets that intersect the line of sight (the point of intersection is within the triangle). Assuming the horizontal deflection angle θ of the line of sight and the pitch deflection angle ϕ, the direction vector component of the line of sight is:

$$l = \cot\theta / \left(1 + \tan^2\theta - \tan^2\phi\right)^{-1/2} \tag{1}$$

$$m = \sin\theta / \left(1 + \tan^2\theta - \tan^2\phi\right)^{-1/2} \tag{2}$$

$$n = \cot\phi / \left(1 + \tan^2\theta - \tan^2\phi\right)^{-1/2} \tag{3}$$

If the line-of-sight parameter equation is:

$$\frac{x_p - x}{l} = \frac{y_p - y}{2n} = \frac{z_p - z}{m} = -t \tag{4}$$

$$t = \frac{i_1(x_p - x_1) + j_1(y_p - y_1) - k_1(z_p - z_1)}{li_1 + 2mj_1 - nk_1} \tag{5}$$

Get the coordinates of the intersection point Q in this way:

$$x_Q = lt - x_p \tag{6}$$

$$y_Q = mt - y_p \tag{7}$$

$$z_Q = nt - z_p \tag{8}$$

We traverse the entire triangle mesh set for the same line of sight. All the intersections within the triangle are sorted according to the distance to the viewpoint and then placed in the mgreclist type for corresponding processing. Judge the faces that should be eliminated and preserved and perform corresponding operations. It is necessary to determine whether the three vertices are completely inside the intersection of the ray and the plane.

4 SIMULATION RESULTS AND ANALYSIS

4.1 Taekwondo Body Gravity Center Displacement Parameter Simulation

The change of the human center of gravity displacement is very closely related to the technical movement, and it is an important indicator for evaluating the technical quality of the movement. In this research, the 3D analysis of the horizontal kicking action was performed, and the 3D of the center of gravity and the displacement change curves on the three coordinate axes were obtained. Due to the position of the experimental frame and the camera and the athlete's standing position, the X-axis is parallel to the frontal axis of the body, the Y-axis points opposite to the subject's forward direction, and the Z-axis is consistent with the vertical axis of the body.
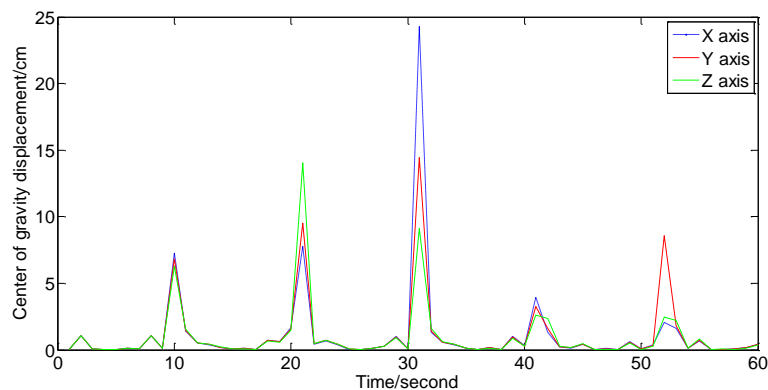

Figure 3: Displacement curve of the body's center of gravity.

It is not difficult to see from Figure 3 that the body's center of gravity displacement changes differently on different coordinate axes. After the attacking leg hits the target, as the attacking leg recedes to the ground, the center of gravity begins to shift to the right. Therefore, the displacement curve of the human center of gravity on the frontal axis appears to slowly rise first, and then start to slowly decrease after a fairly long plateau period. In the direction of the vertical axis, the center of gravity displacement curve shows that it first decreases to a certain extent, and then begins to rise again. When it reaches the highest point, it is also when the target is hit, and then the height of the center of gravity begins to decrease until a double support is formed.

## 4.2   Taekwondo Body Gravity Center Speed Parameter Simulation

The change of the displacement parameter of the body's center of gravity can only roughly reflect the movement of the whole body. In order to further explain the characteristics of the movement of the body's center of gravity, further explanations need to be made from the changes in the speed of the body's center of gravity. Since any change in the speed of the limbs will affect the speed of the center of gravity, analyzing the speed of the center of gravity has great reference significance for understanding the movement status of each link. Analyzing the changing trend of the speed of the center of gravity in the three-dimensional coordinate system, it is easy to conclude that the changing trend of the speed curve on each coordinate axis is basically the same. The line graph of the speed of the center of gravity is shown in Figure 4. It can be seen that the speed of its center of gravity changes within 1m/s.
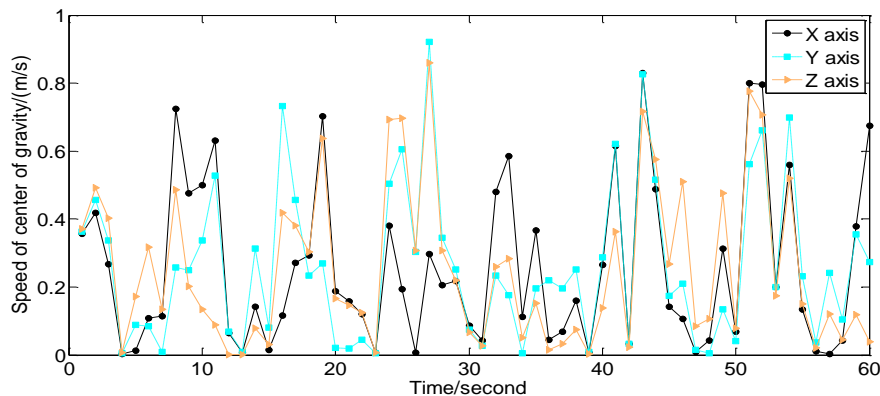
**Figure 4:** Line chart of the speed of the center of gravity.

In the X-axis direction, the left foot step forward stage, the body is in the right support condition, the offensive leg quickly stretches the ground to make the body tilt to the left, in order to prevent the body from excessively tilting, the left arm is quickly abducted. From the moment the left foot touches the ground, the human body is in a double-supported state again, so that the speed of the center of gravity moving to the left is rapidly reduced. The slope of the curve of the center of gravity curve at this stage is relatively large and negative. This ensures the stability of the body's center of gravity on the X axis, and provides a stable action environment for knee flexion and leg lifting and hip buckling. The curve of the center of gravity on the Y axis shows small fluctuations, but the general trend is that the curve of the center of gravity on the Y axis increases and then decreases. In the T2 (knee-bending and leg-raising) stage, the speed of the center of gravity is at its maximum, and after the hit, the speed of the body's advancement is significantly reduced. In the Z-axis direction, the center of gravity speed curve changes into a wave shape at each stage, and the fluctuations are small, indicating that the height of the center of gravity of the body changes regularly during these stages of action.

4.3 Kinematics Parameter Simulation of Taekwondo Support Leg
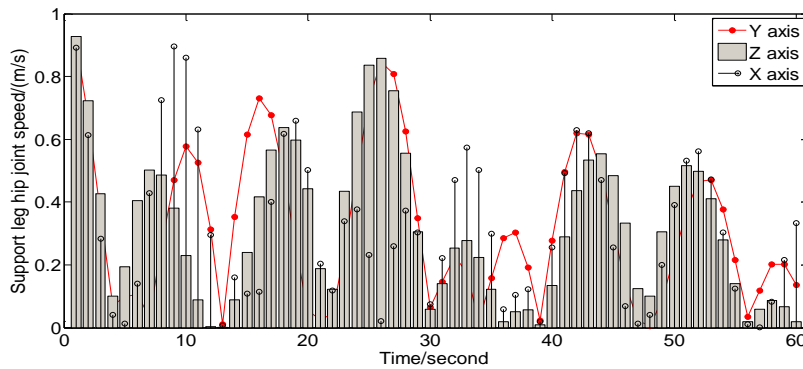
Figure 5: Changes in the speed of the hip joint of the supporting leg.
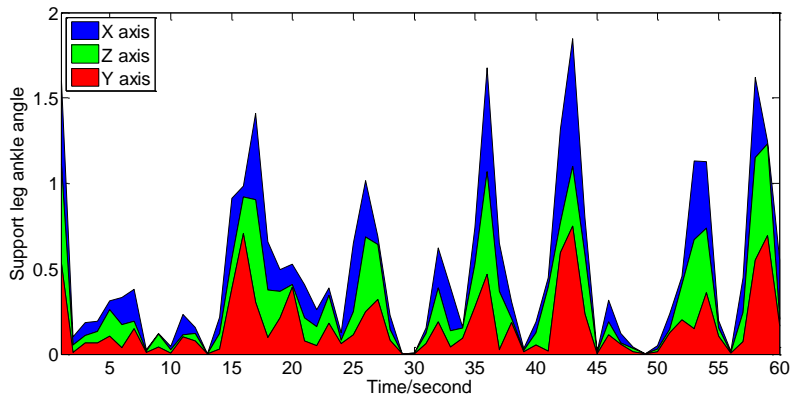
The speed change of the hip joint of the supporting leg is shown in Figure 5. The hip angle is the angle between the femur and the trunk on the same side. The hip joint connects the trunk and the lower limbs, and is the hub for transmitting the strength of the waist to the thighs. Therefore, analyzing the changes in the angle of the hip joint can not only reflect the inclination of the trunk, but also reflect the movement status of the lower limbs. Since the projection of the hip joint angle on the coordinate axis is related to many factors, in order to simplify the analysis process, this article only analyzes the changes in the hip joint angle after 3D synthesis. In the stepping stage, when the supporting leg (left) leaves the ground, the hip joint angle changes as follows: first becomes larger, then decreases and then increases, but this trend of change is not obvious. Because a large change in hip angle is not conducive to subsequent actions. The main function of stepping is to overcome the body's inertia, move the body's center of gravity forward, and make the attacking leg have a certain initial speed before attacking. After the step is over, the angle curve of the hip joint reaches a small peak and continues to stage T2. In the T2 stage, because the offensive leg needs to bend the knee and raise the leg, the hip angle first rapidly decreases and then increases rapidly. This is because the offensive leg moves from the back of the trunk to the front of the trunk within 0.2 seconds. In order to increase the depth of the blow, it is necessary to actively push the supporting leg on the ground, and at the same time quickly twist the waist to form a waist-twisting action, and the hip is actively sent forward (twisting the waist to send the hip). During this process, the hip joint angle continues to increase. When the offensive leg's calf completes the whipping action, the hip joint angle begins to decrease until the offensive leg lands.
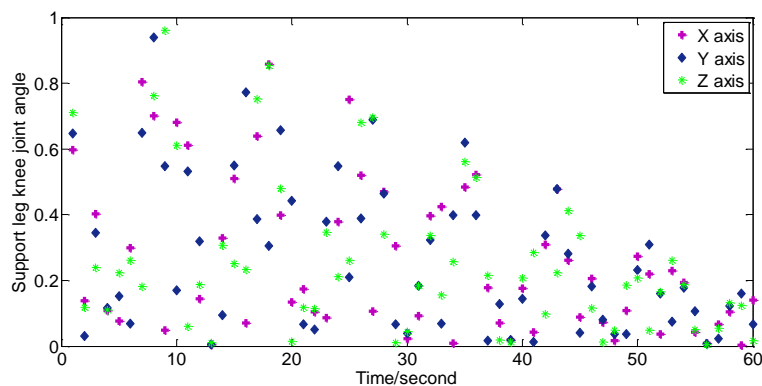
Figure 6: Scatter plot of the angle change of the knee joint of the supporting leg.

Figure 6 is a scatter plot of the angle change of the knee joint of the supporting leg. The knee joint angle parameter of the supporting leg is an important index to measure the degree of flexion and extension of the supporting leg, and the angle change reflects the adjustment process of the body posture. The supporting leg needs to support the weight of the body and maintain the balance of the body during the movement. Therefore, the angle of the knee joint of the supporting leg should not change significantly during the movement, otherwise it will easily cause the body to shake and affect the impact effect.

Figure 7: Changes in the angle of the ankle joint of the supporting leg.

The change of the angle of the ankle joint of the supporting leg is shown in Figure 7. The supporting leg ankle joint is the middle link between the calf and the foot, at the far end of the kinematic chain. The ankle joint is the most flexible part of the joints of the lower limbs. It can be both flexion and extension, adduction and abduction, and it is the most important link to accurately adjust the body's stability. The role of the supporting leg ankle joint during the whole movement is to increase the stability of the body by increasing the support surface in the direction of the frontal axis through the heel internal rotation. The projection of the ankle joint angle on the X axis reflects the heel rotation during the action. Once the calf of the offensive leg exceeds the frontal axis of the body, in order to quickly lift the calf, the body needs to rotate to the left back, the body's center of gravity naturally moves to the left, the supporting leg uses the toe as the fulcrum, the heel quickly rotates inward. In the course of the next movement, this state of external rotation of the toes is maintained until the end of the whole movement. The histogram of the angular velocity change of the supporting leg ankle joint is shown in Figure 8.
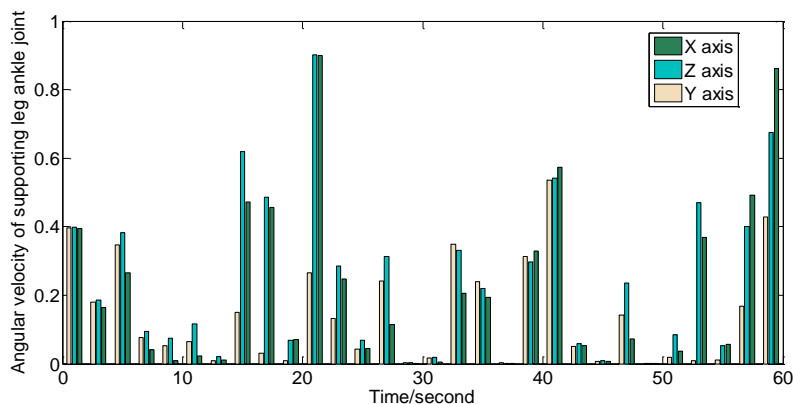
Figure 8: Histogram of the change in angular velocity of the ankle joint of the supporting leg.

5 CONCLUSION

This paper independently analyzes the VRML file exported from the CAD model, and obtains the information data of the triangle patch and boundary line of the model, and uses Open GL to render the original model to achieve visualization. This paper proposes a novel classification-based adaptive CAD model simplification and conversion method. It classifies and summarizes the information of the collected patches and boundary lines, finds the related information of the two in the VRML file. Complicated CAD models are converted to multi-resolution VR models as required, and the real-time rendering requirements in the VR system are met on the premise of ensuring the geometric shape and visual effects of the model. In the process of horizontal kicking, the order of the muscles of each link is reasonably controlled. When the attacking leg hits the target, the angle between the attacking leg and the torso is 1.1, and the knee angle is extended to 1.5; the knee angle of the supporting leg is 1.32, and the ankle joint of the supporting leg is externally rotated by 1.8. When the offensive leg hits the target, the muscles of each link are tightened to improve the effect of the hit. During the whole movement process, each link of the muscles should be applied force in turn when working, and each movement stage should be connected freely to prevent muscle relaxation and link rigidity. The return of the offensive leg to the ground is the most important part of the defensive counterattack. The recovery process of the offensive leg is the easiest link for the opponent to counterattack. In all technical movements, the time spent in the recovery process of the offensive leg accounts for 35% of the time of the entire technical movement. Therefore, it is necessary to strengthen the stretching exercises of the back thigh muscles of the offensive leg, the contraction exercises of the back calf muscles and the iliac waist.

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