
Modeling and Simulation of Virtual Clay Pigeon shooter Training System

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Abstract

As a popular sports event, clay pigeon uses real guns and bullets as its tools. To improve the training effect, reduce its cost and danger, the development of a real-time interactive and perceptive virtual training system by using simulation technology becomes urgent. This system uses Visual C++ (Vega) Creator as its development platform to conduct modeling and simulation of clay pigeon's and grapeshot's flying path and the collision effect of the two objects.

Keywords: virtual training system, simulation technology, real-time, interactive, perceptive

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1. Introduction

Clay pigeon originates from early hunting and military fighting [1]. As an interesting sports event, it is very popular among westners, but it also poses a series of issues: (1) it uses real guns and bullets as its tools, raising the training cost and danger; (2) the constant change of shooting condition, technique difficulty and sports rule greatly influence the training effect. To solve these problems, simulation technology is applied here to develop a virtual training system, which can also be employed in military exercises.

2. The Recent Development in the Study of Virtual Reality Technology Both Home and Abroad

The virtual reality technology is an important direction of simulation technology, including simulation technology, computer graphics, human interface technology, sensor technology and network technology. It is a challenging cross-technology. The virtual reality technology is widely used in many field [2], such as the training of surgical operation [3], virtual classroom [4], industrial production [5] [6], tourism [7], distance-education [8] [9] and is changing the traditional human-computer exchanging model; by simulating the human sense of touch [10], smell [11], taste [12] and listening [13], this technology can introduce the user into a virtual world created by the computer and achieve the two parties' real-time interaction, thus forming a user-friendly multi-dimensional information space.

3. Design of the Virtual Training System for Clay Pigeon Players

With the fast rise in the difficulty of the modern sports event, more and more scientific technologies are applied in the training of the players [14]. Because this training requires the participation of the player's smell, touch, listening and other senses, the simulation technology based on VR will inevitably be used in the sports field. In the development of this virtual training system, WinNT and WinXP professional version, VC++, Vega, Creator, Matlab are employed in a LAN platform. This system uses firearm photoelectric spotting technology, simulation of the shooter training scene, three-dimensional visual network transmission and peripherals synchronization control.

4. Modeling of the Training System

Two models are involved in the process: the moving model of clay pigeon and grapeshot, which will be introduced in the following paragraphs respectively.

4.1 Model of the Multi-Directional Clay Pigeon

(1) With air resistance being zero, the clay pigeon model can be roughly described as a parabola movement, as shown in Equation(1), in which v 、 α' 、 t are respectively the original velocity, angle and time of projection, and the velocity of acceleration gravity is 9.8m/s^2 .

$$\begin{cases} x = v \cos \alpha' t \\ y = v \sin \alpha' t - 0.5gt^2 \end{cases} \quad (1)$$

(2) Taking the air resistance into consideration, the real movement of the clay pigeon is more complicated. The direction of the resistance is against that of the flying clay pigeon, its speed is influenced by the relative speed. When the later is relatively small, the resistance f is in direct ratio with the moving speed v of the object [15]. Since the stressed area of the clay pigeon is relatively big in when it is flying, the equation should be (2). In which b' is the coefficient of the air resistance and s is the stressed area.

$$f = sb'v \quad (2)$$

β' is the intersection angle formed in the vertical direction when the clay pigeon is projected; Δt is continuous variables along the time axis. When Δt is extremely small, the system will be a serial one. Since the frame rate of Visual C++ is 30frame/second, which means the screen will be refreshed 30 times per second, the clay pigeon model can be roughly designed as a discrete one without worrying about compromising the real visual effect. In this way, the motion model can be simplified, and the motion efficiency can be improved. The related equation is shown in the following, in which, b, c, d represent the accelerated speed in the horizontal direction respectively; v_y , the vertical direction of positive timing, and v_y , the vertical direction of negative timing. When v_y is bigger than zero, the clay pigeon is rising, confronted with both air resistance and buoyancy, its value is 0.6; in the horizontal direction, it turns into 0.2, because the air resistance at this time is the minimum one; while in the vertical direction, it changes to be 0.4, since the resistance here is moderate.

4.2 The Motion Model of Grapeshot

In order to achieve the best simulation effect, the initial serial of grapeshot is a random number got through congruence method. Its iterative formula is shown as (4), (5), in which a, M , and initial value x_0 are all positive integers, M is a random digital evenly distributed among $[0, 1]$.

As Reference [16] shows, when the grapeshot is moving in the air, it will confront both air resistance and gravity. In a standard meteorological condition, its flying trajectory can be seen as a parabola when the distance between the shot point and trap machine is 10m, 25m, and 50m respectively, and the maximum flight of this grapeshot is 75m, as shown in Equation (6). The standard weather condition is: $t_0=15^\circ\text{C}$; $p_0=100\text{kPa}$; $\rho_0= 1.206\text{kg/m}^3$; no wind and rain. In this equation, M_e is the quality of grapeshot, v is its flying velocity, ρ_0 , the air density, C_D , head resistance coefficient, \bar{S} , the frontal area of the vertical direction. Equation (6) will turn into Equation (7) after variables separation and integration, in which, R is the flight of the grapeshot away from the burst point, v_R is its flight velocity at R . In the error analysis, the grapeshot's diameter is designed as 3mm and its weight, 24g, based on Reference [16], the maximum flight of a clay pigeon in the 10m clay pigeon event is 66m when $C_D=0.97$, $\rho_0=1.293\text{kg/m}^3$, ρ_0 represents the standard air density. Substitute this number into Equation (5), the value of v_R is clear; then through Equation $v_0-v_R=\Delta v$ and Δv^*t (time taken for a clay pigeon to reach R), we can get the lead value a shooter need before aiming at the target.

$$\begin{cases}
 v_{x_{k+1}} = (v_{x_k} - b\Delta t) \times \sin \beta' \\
 v_{y_{k+1}} = (v_{y_k} - b\Delta t) \times \cos \beta' \\
 v_{z_{k+1}} = \begin{cases} v_{z_k} - (c + g)\Delta t & (v_z \geq 0) \\ v_{z_k} - (d + g)\Delta t & (v_z < 0) \end{cases} \\
 x_{k+1} = x_k + v_{x_k} \Delta t - 0.5b\Delta t^2 \\
 y_{k+1} = y_k + v_{y_k} \Delta t - 0.5b\Delta t^2 \\
 z_{k+1} = \begin{cases} y_k + v_{y_k} \Delta t - 0.5(c + g)\Delta t^2 \\ y_k + v_{y_k} \Delta t - 0.5(d + g)\Delta t^2 \end{cases} \\
 b = \frac{0.2 \times 0.025 \times 0.11 v_{x_k}}{0.105} \\
 c = \frac{0.4 \times 3.1415926 \times 0.055^2 v_{y_k}}{0.105} \\
 d = -\frac{0.6 \times 3.1415926 \times 0.055^2 v_{y_k}}{0.105}
 \end{cases} \quad (3)$$

$$x_{i+1} = (ax_i) \bmod M \quad (4)$$

$$u_{i+1} = x_{i+1} / M \quad (5)$$

$$M_e \frac{dv}{dt} = -\frac{\rho_0 v^2}{2} C_D \bar{S} + G \quad (6)$$

$$v_R^2 = v_0^2 e^{-\frac{C_D \rho_0 \bar{S}}{2M_e} R} + \frac{2G}{\rho_0 C_D \bar{S}} \quad (7)$$

5. Modeling and Simulation of the Clay Pigeon Shooter Training System

The purpose of this modeling and simulation is to create a platform to achieve human-computer interaction. To get the best simulation effect, all the related parameters of the real shooting site and the clay pigeon in its static state must be studied carefully. The system includes: the training site, modeling of grapeshot and clay pigeon, and modeling of the two's flight, test of whether the grapeshot hits the clay pigeon. Here, Multigen Creator is specially used to get high-quality three-dimensional visual database.

5.1. Open Flight Model Database

Open Flight is a database norm developed by Multigen paradigm to describe a scene. In a clay pigeon shooter training system, its filename is "field.flr". db is the root node of the database, in which, the name of the first group is field; under this root node, there are 6 group nodes, they are respectively the shooting site (shooting position, passageway of the shooter, trap machine, foundation, control target room, desks for the shooter to place firearms), gate of the playground, rockwork, trees, auditorium and buildings. After separating modeling of each module, external reference technology is used to include all these modules into the general module in the scene file "field.flr".

5.2. Texture Mapping

In this system, flowers, grass and trees can all be simulated through texture mapping. In File "flr", Creator is used to choose the target area to add textures.

5.3. External Reference Technology

In a virtual training system, all the important modeling scenes, including shooting position, passageway of the shooter, trap machine, foundation, control target room, desks for the shooter to place firearms are integrated through external reference technology.

5.4. DOF Technology and Three-Dimensional Optimization Technique

DOF technique can make the module become mobile, that is, the DOF node can control the movement and rotation of all the child nodes according to the designed degree of freedom. In the training system, design of the entrance of the control target room applies this technique. The detailed process is shown as the following: first, Creator is used to create the DOF node in the hierarchy view of the model database; second, set the entrance of the control target room as the child nodes of DOF node; third, design the left axis of the door as the x axle of the local coordinate system, and this coordinate system rotating around the x axle, and set the degree of freedom as 0~90°; last, open the DOF viewer to preview the movement of DOF node. In this process, two major optimization techniques, adjustment of the hierarchical structure of the database and reduction of the number of the polygon are used.

5.5. Driving and Achievement of the Virtual System

This training system uses the virtual programming method in Vega to drive the whole system. When the modeling of the entire system is finished, the real-time wandering technique in Vega can then be employed.

5.6. Relevance Between the Photoelectric Spotting System and the Position of the Shooting Point of the Virtual Training System

This system integrates MATLAB, Vega, using the strong computing capacity of the first to conduct real time computation, the second, as the front stage support, and the third, as the channel to achieve the real-time data transmission between the front and back stage. The photoelectric image acquisition system and picture processing software are used to compute the coordinate of the hitting point and the posture of gun; then the data is transmit to the geometric model of the bullet through the interface program in C++ to spot the special position of the aiming line in the virtual scene according to the attitude angle of the gun, thereby to simulate the shooting and exploding effect of the gun.

5.7. Collision Detection in Vega

In the training system, small grapeshot is chosen and clay pigeon is taken as part of the scene to simply the collision detection process and reduce the workload of intersection test. VGIS_Z and VGIS_BUMP are used to judge whether the collision between grapeshot and clay pigeon occurs; VGIS_LOS, the collision between the line of sight and building; VGIS_TRIPOD, to adjust the line of sight. The effect of the first collision in the above should be checked with callback function and the volume of LOS is a piece of segment stretching forward from the present point of sight. When this segment has a point of intersection with the building in front to of it, the collision happens.

6. The Simulation Effect of the Training System

In this system, the roving state, as shown in Figure 1, can be entered after setting roving method, environment color and other variables. After pressing the micro switch of the virtual gun, the bullet will be shot through the muzzle. The screenshot of the clay pigeon and grapeshot flying simultaneously in the air is described in Figure 2 and that of the collision detection between clay pigeon and grapeshot, in Figure 3, in which, the red point reveals the collision between the 193rd grapeshot and the clay pigeon.



Figure 1. The initial position of roving



Figure 2. Screenshot of the clay pigeon and grapeshot flying simultaneously in the air



Figure 3. The 193rd grapeshot in the collision detection

7. Conclusion

This paper has presented modeling and simulation of virtual clay pigeon shooter training system to improve the training effect, reduce its cost and danger, the development of a real-time interactive and perceptive virtual training system. This modeling and simulation uses Visual C++ (Vega) Creator as its development platform to conduct modeling and simulation of clay pigeon's and grapeshot's flying path and the collision effect of the two objects. This system uses firearm photoelectric spotting technology, simulation of the shooter training scene, three-dimensional visual network transmission and peripherals synchronization control.

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References

- [1] Yu Jiying. *Olympic Shooting*. Beijing: People's Sports Publishing. 2000: 5-15.
- [2] Chen Haolei, Zou Xiangjun, Chen Yan, Liu Tianhu. Overview of the advance in virtual reality technology. *SCIENCEPAPER ONLINE*. 2011; 6(1): 1-3.
- [3] Vanessa N Palter, Teodor P Grantcharov. Virtual Reality in Surgical Skills Training. *Surgical Clinics of North America*. 2010; 90(3): 605-617.
- [4] Mamoun Nawahdah, Tomoo Inoue. Setting the best view of a virtual teacher in a mixed reality physical-task learning support system. *Journal of Systems and Software*. In Press, Corrected Proof, Available online 6 September 2012.
- [5] Zhang Xiaoqiang, Wang An, Li Jianzhong. *Design and Application of Virtual Reality System in Fully Mechanized Mining Face*. Procedia Engineering. 2011; 26: 2165-2172.
- [6] Xin Wang, Jun Yao. Selection and Simulation of Electric Steering Gear Control System. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(6).
- [7] Daniel A, Guttentag. Virtual reality: Applications and implications for tourism. *Tourism Management*. 2010; 31(5): 637-651.
- [8] Liangyu Lei, Jianjun Liu, Xiufang Yang. *Research of the Remote Experiment System Based on Virtual Reality*. Physics Procedia. 2012; 24(Part B): 1199-1206.
- [9] Hua Li, Jing Bai, Shujian Liao, Juanping Wu. Simulation models for MIMO wireless channels. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(1): 158~166.
- [10] Francis J Keefe, Dane A Huling, Michael J Coggins, Daniel F Keefe, M Zachary Rosenthal, Nathaniel R Herr, Hunter G Hoffman. Virtual reality for persistent pain: A new direction for behavioral pain management. *PAIN*. 2012; 153(11): 2163-2166.
- [11] S Brewster, D McGookin, C Miller. *Olfoto: Designing a Smell-based Interaction*. CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems. ACM Press, New York. 2006; 22-27: 653-62.
- [12] D Drayna. *Human Taste Genetics*. Annual Review of Genomics and Human Genetics. 2005; 6: 217-235.
- [13] Silvia Erika Kober, Christa Neuper. Using auditory event-related EEG potentials to assess presence in virtual reality. *International Journal of Human-Computer Studies*. 2012; 70(9): 577-587.
- [14] Li Xiangchen, Sun Jinhai. *Sports System Simulation*. Beijing: People's Sports Publishing. 2004: 6-20
- [15] Li Wugang. Numerical analysis of the drag coefficient and the mass of the object Projectile Motion. *Journal of Guangxi Teachers Education University (Natural Science Edition)*. 2006; 23(2): 112-114.
- [16] Chen Zhigang, Zhao Taiyong, Hou Xiucheng. *Explosion and its terminal effect*. Beijing: Ordnance Industry Press. 2004: 240-244.