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Study of Tennis Assisted Training Systems Based on Motion Tracking

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Abstract: In this study, a mathematical model of tennis track was established through studying the relationship between the movement and placement of tennis. And this model is applied to the tennis training simulation system. The experiments results indicated that the model can simulate the tennis track of an athlete after hitting effectively, and the placement probability tolerance was less than 8 cm. The design and study of this system provided an accurate calculation basis for the computer aided tennis training system.

Keywords: Tennis auxiliary training system, Trajectory simulation, Algorithm

INTRODUCTION

Sports analysis plays an important role in competitive sports and technical sports fields. The motion aided training system designed and developed based on video recognition technology, will become an important direction of sports training in the future. Video based motion analysis technology can not only obtain any accurate and comprehensive movement data of athletes through image pickup devices without any interference from the athletes, but also can analyze the movements of athletes, help coaches and athletes to find non-standard movements or wrong actions, and improve the efficiency of sports training and improve sports skills, so as to achieve the purpose of auxiliary training of sports.

With of hundred years of development and deposition, a set of colorful tennis tactics theory has been constructed, and the Tennis placement is always the core content of theoretical research and practice training of tennis [Liu, *et. al.*, 2011]. In sports, an accurate grasp of the placement of tennis is the basis of scoring in the attack, is an important offensive technique of tennis, and is also an important part of tactics [Kong, *et. al.*, 2010]. To win, you must have good service technique and high impact rate. Otherwise even the players own the best other techniques, perfect tactics, if the ball did not fall within the set regions finally, will also come to naught, and will not reach the attack goals. In sports, the control of the point is an important factor to decide the outcome of the, especially in the international top tennis matches, when opponents are well-matched in strength, it often happen that 1 point to decide the outcome [Zhang, 2010]. Who wins 1 point at the key moment, can turn the tide by applause.

With the development of the times, computer technology is used in more and more sports [Wang, *et. al.*, 2011]. Nowadays, computer is playing more and more important roles in athletes training, international competition referee assist, and tactical instructions in games. In tennis sport, the main factors affecting tennis placements include air resistance, landing distance, the ball speed and ball, rotating sphere, the athlete's body movement parameters, athlete's psychological quality and technical and tactical level, etc. AT the moment, the computer simulation study of tennis placement is mainly that, we put the tennis as a particle to discuss basketball trajectory under no air resistance. For example, in the famous SPG sports game "World Tennis Competition 2009", the tennis trajectory is designed only considering the gravity and without other factors such as air resistance. But the real process of basketball games, the tennis will be affected by the influence of gravity and air resistance. Usually the faster the ball flying, the greater the air resistance will be. And the flight trajectory is non standard projectile motion, namely the throw point and landing points are not in the same horizontal line. So the discussion without air resistance tennis angle has little practical significance. This paper mainly studies on condition of air resistances exist both in the horizontal and vertical directions, the tennis trajectories under different release height, angle and speed from hit point. But in the real basketball games, the ball's running will affected by air resistance and gravity. The ball flying faster, the greater the air resistance will be. And the flight trajectory of the ball is non standard projectile motion, namely the throw point and landing points are not in the same level, so the discussion without air resistance tennis angle is of little practical significance.

In this paper, we mainly studied that when air resistance exists both in horizontal and vertical directions, how the ball flight trajectories would be with different release height, angle and velocity, so

that the exact angles of shot could be calculated. And the hitting points and angles be display in the way of visualization.

THE MAIN MODULES AND FUNCTIONS

Main functions of computer simulated tennis placement assistance training system (CSVPATS). The athlete goes to the virtual tennis venue act the serve training according to the prompts. The net appears when training start. The shooting speeds and hand postures in real scene will be caught by using the Microsoft Kinect, and the virtual image of the player hits the ball will be displayed on the screen. An empty GameObject was set in the right hand of athletes to generate tennis position. If the tennis hit the designated position, the sound of applause will play[7]. Not hit, the ball failed sound will play. In the upper left corner of the scene shows the current score, the highest score record and game time. Tennis has a physical material, and could continue to bounce after landing. After the training, the trainer could register online, and send the training score to the remote server fraction to record the training data. The athlete can also update his scores, check the historic scores. The system mainly consist the following modules, the shot angle and shot speed calculation module, data acquisition module, statistics module and the display module, the construction is showed as fig. 1.

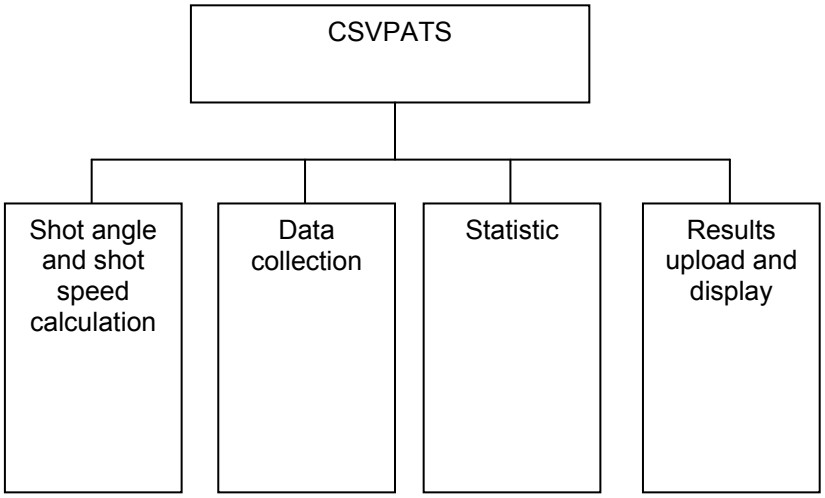

Fig.1 Structure diagram of CSVPATS

REALIZATION OF SYSTEM FUNCTIONS:

Shot angle and shot speed calculation module:

Set up the running track equation group of tennis: The flight path of the tennis is shown in Figure 2. In which v refers to the flight speed of Tennis, v_0 refers to the release speed of tennis, θ refers to the angle that tennis flying direction turns clockwise to positive axis. α refers to the angle of Tennis. And we get formula 1 .

$$\begin{cases} v_x = v\cos\theta \\ v_y = v\sin\theta \end{cases} \tag{1}$$

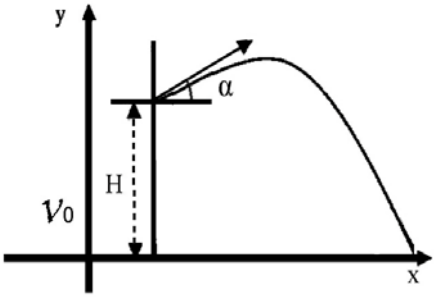

Figure.2 Flight trajectory of Tennis

The horizontal and vertical resistances are formula(2).:

$$\begin{cases} F_x = F\cos\theta \\ F_y = F\sin\theta \end{cases} \tag{2}$$

In the air, the air resistance formula $F = -kv^2$ Multiplied $\cos\theta$ or $\sin\theta$ on both side, we get formula (3).

$$\begin{cases} F_x = -kvv_x = -k\sqrt{v_x^2+v_y^2}\,v_x \\ F_y = -kvv_y = -k\sqrt{v_x^2+v_y^2}\,v_y \end{cases} \tag{3}$$

According to the Newton's second law differential equation for inclined projectile objects can be listed in the air resistance. See in Formula (4):

$$\begin{cases} -kv_x\sqrt{v_x^2+v_y^2} = m\dfrac{dv_x}{dt} \\ -(kv_y\sqrt{v_x^2+v_y^2}+mg) = m\dfrac{dv_y}{dt} \end{cases} \tag{4}$$

Set up the best angle parameter equation: Formula (4) is a first order ordinary differential equation with variable coefficients. To obtain the optimal projection angle parameter equation, we must according to the following three steps. First, figure out v_x, v_y; Second, figure out x, y; The last, according to expressions of x, y, to derive to equation to calculate the best shot angle equation.

From figure 2, we could know that $v_y = v_x \tan\theta$, have $\tan\theta = q$, then we get the formula (5)

$$v_y = qv_x, dv_y = qdv_x + v_x dq \tag{5}$$

The two formulas in the formula (4) be divided, and the formula (5) be introduced in. simplified and get formula (6)

$$\sqrt{1+q^2}\,dq = \frac{mg}{kv_x^3}dv_x \tag{6}$$

Integra on both side and the results could be seen in formula (7)

$$\int_{q_0}^{q}\sqrt{1+q^2}\,dq = \int_{v_{x0}}^{v_x}\frac{mg}{kv_x^3}dv_x$$

$$\frac{1}{2}\left[q\sqrt{1+q^2}+\ln(q+\sqrt{1+q^2})\right]-\frac{1}{2}\left[q_0\sqrt{1+q_0^2}+\ln(q_0+\sqrt{1+q_0^2})\right] = \frac{mg}{2k}\left[\frac{1}{v_{x_0}^2}-\frac{1}{v_x^2}\right] \tag{7}$$

In which α and v_0 are the angle and initial speed of the ball, respectively. And then formula (7) could be concise into formula (8).

$$\frac{1}{v_{x_0}^2}-\frac{1}{v_x^2} = \frac{k}{mg}[f_{(q)}-f_{(q_0)}] \tag{8}$$

Formula (9) could be get from (8) and $v_y = qv_x$

$$\begin{cases} v_x = \dfrac{1}{\sqrt{C-\frac{kf_{(q)}}{mg}}} = \dfrac{1}{\sqrt{C(1-\frac{kf_{(q)}}{mgC})}} \\ v_y = \dfrac{q}{\sqrt{C-\frac{kf_{(q)}}{mg}}} = \dfrac{q}{\sqrt{C(1-\frac{kf_{(q)}}{mgC})}} \end{cases} \tag{9}$$

The Constant C in the formula (9) is seen in formula (10)

$$C = \frac{1}{v_{x_0}^2}+\frac{kf_{(q_0)}}{mg} = \frac{1}{v_{x_0}^2}+\frac{k}{mg}[q_0\sqrt{1+q_0^2}+\ln(q_0+\sqrt{1+q_0^2})] \tag{10}$$

To here, we deduced the exact expression of v_x, v_y and q. Assuming the landing point of horizontal distance from the point of the throw is s, and the landing q be expressed with Q, and the height of the throw point to the land is h, then we get $h = h_1 + L\sin\alpha$ from figure1, in which h_1 is the height of throw point, □ is arm length. Obviously, we could get that y =0 when landing from figure 1. Pay attention to have $Q_0 = q_0 = \tan\alpha$. From formula （9）（10） we could get formula (11)

$$s = \frac{1}{gC}\left[(Q_0-Q)+\frac{k}{mgC}(\varphi_{(Q_0)}-\varphi_{(Q)})\right]-(h_1+L\sin\alpha) = \frac{1}{gC}\left[\frac{Q_0^2-Q^2}{2}+\frac{k}{mgC}(\lambda_{(Q_0)}-\lambda_{(Q)})\right] \tag{11}$$

When the parameters h_1, L, v_0, k, m are given, from formula (11) we know that, □ only determined by α. And now given an α value, a □ value can be calculated by compute. So that formula (11) is to

derive the calculation of the best hitting point of the parameter equation.

Data acquisition module

Since the optimal hitting angle parameter formula group is 3 variables and 2 equations, it cannot get the real solution. So in the data acquisition module requires the use of Microsoft XBOX360 for the development of Kinect to get different speeds and angles. Kinect is a 3D depth camera capable of take 30 frames image per second, we can get a person's action without movement capture device and exclusive mark[9]. It also has the image recognition, audio input, voice recognition and other functions. It used light encoding technology, it is not 2D image encoding technology which often used in the structure light encoding, but the three dimensional

This module is mainly responsible for the realization of each athlete's sports scores automatic statistical scoring functions[11]. Firstly, one or more zones for the best point in the field were set (Figure 3). Using the face recognition function in the Kinect Raw Sensor Streams API, to automatic recognize the participates in the movement. This module makes three kinds of classification to the ground surface area in the simulation scene, show the best placement areas need to be hit by a dark red area on the display or projector, and the shallow red areas represent the best placement outside the second best placement. Other areas to the game show as the background texture map. The player gets 2 points if the ball falls in the best area, and a loud music sounds at the same time. The player gets 1 points if the bal falls in the second best area. The player gets no score if the ball falls in other areas, and the system makes a sound of encoding. Its light source is laser speckle (Speckle Laser), which is the point when the laser beam is irradiated to a rough object or through the glass. These points have a relatively high randomness, and will change with different patterns of distance. For Windows SDK Kinect has driver[10], the original measurement data stream development interface (Raw Sensor Streams API), natural user interfaces. Developers can directly obtain the original data. It can also track the skeleton movements of two users in the field of vision. It also has advanced sound effects, including suppression of noise and echo cancellation function, which can be identified by sound sources in the form of sound, and can be used together with the Windows speech recognition API.

Statistics and analysis module

regret. When the training ended, the system will discharge to all participants.

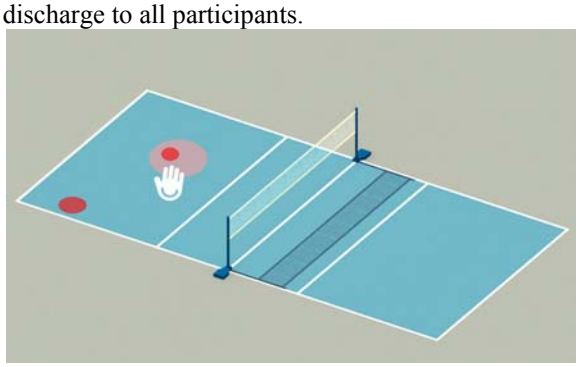

Figure 3. The optimal placement of the interface

The data statistics module of the system take the athletes as the basic storage unit, each athlete's statistical data contains the following items, see in Table 1

Table 1 the field and significance of the athletes' data statistics

Statistical items	Field name	data type	explain
Name	T_Name	Compound	The names of the statistical objects, are consisted by the information Kinect automatic accessed and the user's input (the system automatic identify after the first set)
Training times	T_ Number	Numeric(Int)	To recod the training times of the athletes(System automatic generation)
The optimal placement rate	BIP	Numeric(Rea)	The ratio of the number of players hit the deep red and the number of strokes
The second best placement rate	SIP	Numeric(Rea)	The ratio of the number of players hit the shallow red and the number of strokes
Overall hit rate	IP	Numeric(Rea)	SIP+BIP
Best shot height	BSH	Numeric(Rea)	The average value of the shot heights when the players hit the deep red area

Best shot angle	BSA	Numeric(Rea)	The average value of the shot angles when the players hit the deep red area
the best ht time rate statistics	BT	Time	The average value of the shot times when the players hit the deep red area
Overall ranking	GR	Numeric(INT)	Ranking among all the athletes who participated in the training

Results upload and display module

The database used in this study is Access2003 standard database. Access database is the standard database of Microsoft company's products, which has a wide range of applications in all aspects of Windows[12]. The database has good general performance, and has good compatibility. Therefore, the technology was chosen as the first selection to establish a new database, and four tables are included in the database, they are Game, Password, Player, Team, which are used for storing game records, passwords, players information, team information, etc.

After several trainings, athletes can upload their own sports data, and get the statistics of their batting scores and fell on the best placement success rate. Through comparing the statistical results, the coach can grasp the characteristics of the athletes and the best time to exercise according to the statistics of the athletes.

RESULTS AND DISCUSSION

Hit curve calculation results: In order to verify the accuracy of the shot angle and shot speed calculation module, we use Kinect to collect the athletes' movements in the real tennis field, to observe the agreement between the calculated results and the real impact of Tennis. 15 experiments results are shown in Table 2

The experimental results show that when the incident angle reaches 29.32 degrees, at the beginning of the speed reaches 28.45m/s, tennis is unable to fall in the other half normally, the solution has no practical significance. So that only the results of the 9 normal falling ball state are taken. The placement between tennis and calculated the circular error are ranged in 0-9cm, there were 4 direct hits, and 2 hits with error in 2cm. Considering the tiny change of the mass of the sphere and the change of the complicated air resistance after the rotation, the error is within the acceptable range.

Table 2. The deviation of the real fall point and the software calculated value

Initial stroke speed (v_0 Unit: m/s)	Hit angle (α Unit：°)	Hit height (H Unit m)	q_0	Circle probability error (cm)
10.765	24.582	2.014	0.984	2
11.301	23.137	2.182	0.967	0
11.987	21.542	2.215	0.956	5
12.543	20.432	2.142	0.932	0
13.495	14.643	2.412	0.913	1
13.891	15.740	2.475	0.879	0
14.639	12.564	2.549	0.894	4
15.987	9.532	2.601	0.861	0
19.563	10.32	2.583	0.757	9

CONCLUSION

The following conclusions are obtained through the design and development of the software.

1) Through the study on the athletes of the stroke angle and the velocity of the ball, a mathematical model is established on the relationship analysis among the tennis movement in the three-dimensional space height, specific amplitude and relationship between ground net. The theoretical foundation for software development has been laid.

2) The software can be used to quantify players hit the ball, and to guide the training, to make it rose from the experience judgment to a scientific judgment.

3）The software introduces the computer software into the training and competition system, which could improve the pertinence of simulation training, and provide a scientific reference for the coaches in commanding on the spot and development of technical, tactical countermeasures.

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