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Simulation Analysis of Optimal Modeling of Tennis Serve Image Path Based on Deep Learning

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Abstract: *With the continuous development of economy, people have more and more choices for recreation and leisure, and tennis has become one of the chosen sports, especially in recent years, the booming development of tennis in China has driven a large number of people to contact tennis. In tennis, the serve occupies a crucial position, so this paper aims to use deep learning technology to study the path of tennis serve images, detect the moving objects from the images, extract the key parts of the action, obtain the relevant information during the movement, conduct a multi-level and scientific study of the serve action, and provide a basis for tennis serve training. This paper proposes to conduct experiments on tennis serve technology using literature method, video observation, comparative analysis and deep learning technology to investigate the serve position, serve action and serve route of sportsmen, and the experimental results show that the height of the ball leaving the hand should maintain a ratio of 0.98 to the height, the instantaneous speed of the ball leaving the hand should reach 4.79m/s, and the minimum angle of the elbow joint in holding the racket should be best maintained at 41°or so, and the angle of the racket-holding elbow joint at the time of action acceptance should preferably be around 112°.*

Keywords: *Deep Learning, Tennis Serve, Serving Technique, Path Optimization*

1. Introduction

1.1 Background

With the rapid development of tennis in the world, especially in 2011 Li Na won the French Open women's singles championship and the Australian Open Grand Slam championship in 2014 with her proud performance, which greatly stimulated the development of tennis in China, but it was found through the study that most people performed generally in tennis serve technique, but the serve, as the basic element of tennis project, is the means for players to play their own characteristics and The lack of serve technique seriously reduces the performance of players in the game, so the study of tennis serve route can help players and coaches to understand the development of modern tennis tactics. This study cultivates the players' good tactical awareness, improves the players' ability to use tactics in the competition, improves the athletes' competitive level, and provides targeted guidance basis for the athletes in tennis training.

1.2 Significance

Although excellent tennis players have emerged in China where tennis is developing rapidly, most of them are fleeting, and those like Li Na can be proud of for a long time are rare. Therefore, the study of tennis serve can improve the level of tennis in general and provide a basis for the development of Chinese tennis career; using image technology to analyze tennis movement can get accurate and comprehensive data without disturbing the players, improve training efficiency, improve technology and achieve the purpose of assisting training.

1.3 Related Work

The boom of tennis in China has triggered an increasing number of people to get involved in the

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sport, thus contributing to the development of tennis theory. Parunchaya presents within-subject variability to assess phase-dependent differences[1].Campbell A suggested that junior tennis players are at risk for low back pain, with potential mechanical etiologies during the serve, and groundstrokes are thought to load this region, so the study compared players with and without a history of LBP in tennis forehand and backhand open and square Low back mechanics in stance[2].Reno V presented a technological platform developed for tennis that is capable of extracting movement sequences and supporting coaches in the analysis of their performance in training and official matches. The main objective is to demonstrate that the proposed combination of hardware and software modules is able to extract sufficiently robust 3D ball trajectories to evaluate ball orientation changes and identify serves, strokes and bounces[3].Kovalchik S A proposed a Bayesian multilevel model of serve times in professional tennis tournaments, which includes heterogeneous mean, variable and covariate effects [4].G, Torres-Luque proposed to analyze 10 variables related to first and second serves using serve boxes (deuce and dominant side) and drop points (wide, body and T-zone) to compare the statistical profiles of male and female high-level tennis players' serves [5]. Krause L M suggested that practice tasks representing match requirements enhance skill learning and transfer [6].Connolly proposed using a 3D motion capture system to capture the kinematic characteristics of the whole body, racket, and ball to compare the kinematic differences between elite junior male and female tennis serves [7].Garry, proposed to use basic physics to investigate measurements related to tennis serve action, and for the serve trajectory used here, a single radar gun located on the centerline of the court actually underestimated the velocity of the wide serve by approximately 3.4% at the point of serve and in impact with the court underestimating by about 14.3% [8]. Although these theories introduce tennis at different levels, they are not perfect for image analysis aspects and need to be further explored.

1.4 Points of Innovation

In the study of service training, the joint of the service arm is color-marked, and the joint coordinates are registered by collecting tennis service images to explore the motion trajectory of the service arm. In this study, an improved tennis serving model is established based on the trajectory of the shoulder serve. The deep learning technology is used for experimental analysis to classify the trajectory of tennis serve, train the accuracy of the serve, and improve the level of tennis.

2. Optimized Modeling Simulation Method of Tennis Serve Image Path with Deep Learning

2.1 Deep Learning Concept and Development

Initially, the name of deep learning idea was "information mirror model", and it evolved into "deep learning" in the subsequent development. The deep learning was developed based on MBD. The initial implementation of model systems engineering in enterprises resulted in different physical and other models that gave rise to the deep learning [9]. NASA described deep learning as a multidisciplinary and multilevel simulation process using data such as physical models to integrate the process as a mirroring tool to react to the lifecycle process of a physical product. In 2003, an American professor proposed the concept of virtual digital representation, which argues that a digital model of a product can express the characteristics that the product itself has. This theory is considered to be the prototype of deep learning, but due to the imperfection of deep learning technology at that time, the collected product information was limited, and it did not produce a scale effect and did not receive attention [10].

With the continuous development of digital technology, model system engineering has been widely used and has evolved to three-dimensional technology, and data is collection has evolved from backward manual to online collection, such as sensor data transmission, which is now often used [11]. After the continuous development of counting technology, deep learning technology has been improved and now can be commonly used in various fields, especially in product manufacturing, medical analysis and engineering construction, but deep learning technology was first applied in the field of maintenance of aerospace vehicles, and American aviation agencies use deep learning theory for model and data analysis such as dynamics model and stress analysis, and use the old to detect whether the airframe needs to be maintenance and to meet a certain mission requirement [12].

2.2 Tennis Serve

The serve occupies the initiative in any competitive event, and for tennis, the serve is the key to scoring. In competitive tennis, if you want to take the initiative, you must break the serve to suppress

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your opponent, and once you successfully suppress in the serve, you have a great advantage for the subsequent matches [13-14]. International tournaments stipulate that a racket must be used to serve, and the tennis ball flies over the net and lands in the opponent's area before the serve is considered successful, whether or not it wipes the net does not affect the success of the serve, if the tennis ball wipes the net and lands in the opponent's area, it is still a successful serve, if it wipes the net and lands outside the opponent's area, it is a failed serve. When serving, the player stands to the left or right of the midpoint of the tennis court and serves toward the opponent's area [15]. It is internationally accepted that the serve can be broken down into tossing, leaning back, racket over the head, using body strength to drive the racket in a certain direction, and tapping the tennis ball so that it lands in the opponent's area; we classify tennis serves as flat serves, topspin serves, and cutting serves. In serving, special attention should be paid to the speed, drop point and spin of the serve [16-17].

2.3 Status of Domestic and Foreign Research on Tennis

(1) Foreign research status

Foreign researchers have investigated the stretching angle in the process of serving and concluded that knee movement has an important influence on the tennis flat stroke serve. The experiment was divided into three groups, with 15 times each of fixed knee angle for serving and not fixed knee serving during serving. The sub-experiments showed that knee motion affects the quality of the serve, independent of the players themselves. Western divided the tennis serve into preparation phase, power phase and follow-through swing phase and suggested that the serve speed is positively related to the speed and acceleration of each body part of the body [18-19]. Since back injuries are becoming more common in the game, John W. Chow et al. explored the relationship between upper body motion and lower kidney muscle activity based on the type of serve, and quantified the upper body and racket into different parts by modeling and calculating the effect of each part on racket speed. British doctors developed the "Eagle Eye" system, also known as the "Instant Replay System", which is now widely used in major tournaments, but was first used in tennis to help umpires make the right call on some controversial decisions.

(2) Current status of domestic research

In order to improve tennis teaching, computer technology is introduced into tennis teaching. The experiment divides the students into two groups. The experiment shows that the use of computer technology to set the scene, the library stimulates students' learning enthusiasm, can actively learn the basic knowledge of tennis, and optimize the teaching results. Liu Hui used the high-speed camera and linear change method to analyze the athlete's body movement when serving the ball. He believed that the tennis serve is a whipping action, and the power is transmitted to the racket through limb movement, and finally the racket gets the power and hitting speed [20]. Some scholars believe that the strength of the trunk and lower limb muscles should be fully exerted, and overemphasizing the upper limb home supervisor will reduce the accuracy of the serve [21].

2.4 Image Detection Methods

Median filtering uses the neighborhood gray value of a pixel point to replace the gray value of a pixel point, which can make the image edges unblurred while excluding noise early due to the significant difference between the selection of gray values and typical values [22]. Widely used in one-dimensional signal processing at the time of its proposal, the sequence signal can be defined as:

$$W = Median\{c_1, c_2, \cdots c_n\} = c\left(\frac{n+1}{2}\right) \tag{1}$$

$$W = Median\{c_1, c_2, \cdots c_n\} = \frac{1}{2}\left[c_{\frac{n}{2}} + c_{\frac{n}{2}+1}\right] \tag{2}$$

Among them, $c_1, c_2, \cdots c_n$ is the original signal in descending order.

The wavelet is constructed by the restriction function la, when its transformation satisfies certain conditions, we call the function the mother wavelet, and its transformation conditions are as follows.

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$$A_\beta = \int_Q \frac{|\beta(\theta)|}{\theta} d\theta < \infty \tag{3}$$

Where $\beta(\theta)$ is the restriction condition.

We translate and stretch the above equation to obtain multiple wavelet functions, which we call function groups, as shown in the following expressions.

$$\beta_{z,x}(q) = \left|\frac{1}{\sqrt{z}}\right| \beta\left(\frac{q-x}{z}\right) \tag{4}$$

Where z denotes the stretching variable, which represents the width of the function, and x denotes the translation, which determines the distance of the translation. So for any function, its wavelet transform can be expressed as

$$T_{zx}(q) = \langle f, \beta_{z,x} \rangle = \int_{-\infty}^{+\infty} f(q) \frac{1}{\sqrt{z}} \beta\left(\frac{q-x}{z}\right) dq \tag{5}$$

Where $T_{z,x}(q)$ is the convolution of the functions $f(q)$ and $\beta_{z,x}(q)$. In the frequency domain there exists.

$$\beta_{z,x}(\varepsilon) = \sqrt{z e^{-j\varepsilon}} \beta(z\varepsilon) \tag{6}$$

During operation, we can observe the frequency of the signal by adjusting z. In the formula, the larger z is, the higher the resolution in the frequency domain, and the smaller z is, the higher the resolution in the time domain. It can be found that wavelet transform has good time-frequency window characteristics, so it is widely used in signal analysis [23].In the continuous wavelet function, z and x need to be taken continuously, so this theory exists only among ideal operations and has no practical application, and in practical applications, z and x must be discrete, from which the following expressions can be obtained.

$$\beta_{s,d}(t) = \frac{}{\sqrt{c_0^s}} \beta\left(\frac{t - dx_0 c_0^s}{c_0^s}\right) = c_0^{-s/2} \beta\left(c_0^{-s} t - dx_0\right) \tag{7}$$

In the above equation, c_0 is the scaling step, x_0 is a positive real number, and s, d are integers. Thus we define the discrete wavelet transform of the expression as:

$$\langle f, \beta_{s,d} \rangle = z_0^{-\frac{s}{2}} \int_{-\infty}^{+\infty} f(t) dt = z_0^{-\frac{s}{2}} \int_{-\infty}^{+\infty} f(t) \beta_{s,d}\left(z_0^{-s} - kx_0\right) dt \tag{8}$$

For color image processing, we need to find the atom that maximizes the inner product of atoms and residuals with minimum error, so we need to recalibrate the deviation of the input map, as follows:

$$\langle e, r \rangle_\chi = e^Q r + \frac{\chi}{m^2} e^Q k^Q K r = e^Q \left(I + \frac{\chi}{m} k \right) r \tag{9}$$

The first term is the definition of the original inner product and the second term is the calculation of the residual inner product of e and r making the selection of atoms taking into account the image color averaging problem, while its definition domain is:

$$\beta_{zx} = \arg\min_{\beta_{zx}} \|\beta_{zx}\|_0 + \theta \left\| \left(l + \frac{\beta}{m} V \right) \left(T_{ZX} \hat{Q} - W \beta_{zx} \right) \right\|_2^2 \tag{10}$$

In case of inhomogeneous noise, we need to know the standard deviation of different noise places, then the noise weights at the defined vector can be expressed as:

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$$\alpha_u = \frac{\min_{u' \in Image} \partial_{u'}}{\partial_u} \tag{11}$$

3. Deep Learning Simulation Experiment for Tennis Serve Image Path Optimization Modeling

3.1 Experimental Objects

(1) In this study, considering the rapidity and transience of tennis serve, we used high-speed camera equipment to record the instantaneous trajectory of moving objects, and a short-time storage system was used in the experiment [24].

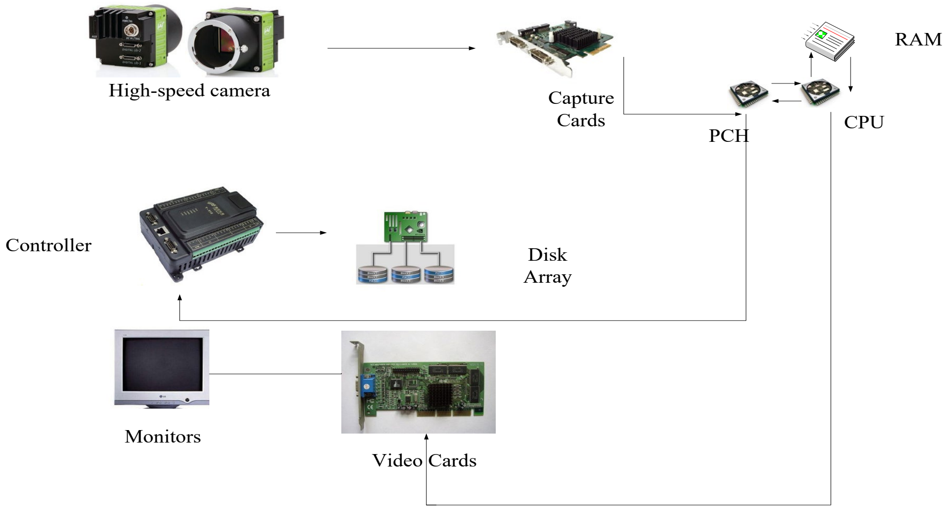

Figure 1: High-speed camera instrument system structure

Figure 1 shows the working structure of high-speed camera equipment, where the process of completing a complete set of data acquisition is usually only a few seconds or less. However, it is necessary to maintain a long tracking record of a high-speed moving object, and a huge amount of data energy is generated in the process. Finally, the high-speed camera equipment will save the tennis serve image through the acquisition card in the computer for professional analysis [25].

(2) Basic information of experimental players

In this paper, we explore the characteristics of different sports players according to their serving styles, routes and tennis ball landing points, and analyze the different effects of different serving actions on the tennis serve effect by collecting the different work of the sports players' bodies when they perform the tennis serve action.

Table 1: Basic information of the observer

Observers	Age	Height (cm)	Body weight (kg)	Grip
A	25	173	68	Double Anti
B	27	176	70	Double Anti
C	28	182	63	Double Anti

Table 1 lists the athletic personnel who performed the experimental observation, firstly, there is a small influence factor in the age of the subjects, but there is still a certain difference in the height of the subjects and a small difference in their weight, and finally, in the grip mode, the subjects are all right-handed grip and double reverse.

3.2 Experimental Data Collection Experimental Results Analysis

In the experimental process, all the athletes stood on the playing field according to the requirements of the competition, and the playing field we arranged according to international standards, as shown in figure 2.

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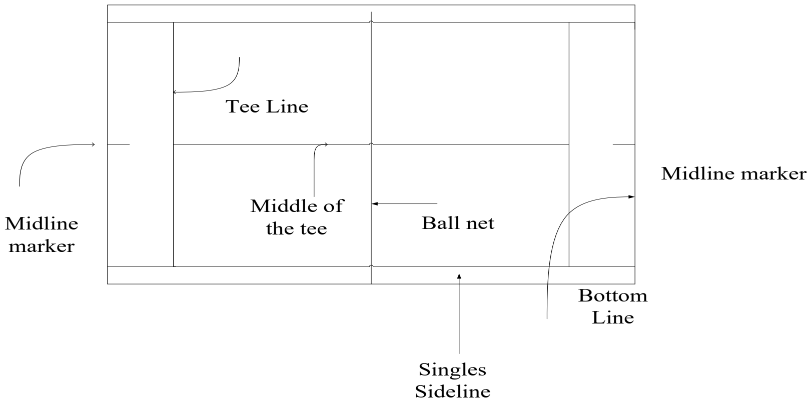

Figure 2: Sketch of tennis court

The number of serves is the same, in this process, we use high-speed camera apparatus for motion capture, if it is a valid serve then we record it as a successful serve, anyway it is recorded as a failed serve, but during the recording process, the sports person will not know any information to prevent anomalies in data collection.

Table 2: A serving statistics

Sessions	A One-shot success rate (%)	A one-shot score rate (%)	A Two-shot score rate (%)	ACE Ball	Missed Ball
1	43	45	27	3	5
2	41	37	29	1	3
3	47	39	30	1	4
4	49	40	28	2	5
5	39	43	32	1	2
6	52	41	27	0	5

According to the data in Table 2, this study finds that the overall level of personnel is still good, and the success rate is stable between 39% and 52%, but the overall level still tends to be low. The higher service success rate is coincidental. The total score rate is maintained at about 40%, and the overall difference is small. It was found that the success rate of two shots dropped more than that of one shot, indicating that the level of service personnel was unstable, and the number of ACE balls and the number of lost balls remained within the normal range.

4. Simulation Analysis of Tennis Serve Image Path Optimization Modeling with Deep Learning

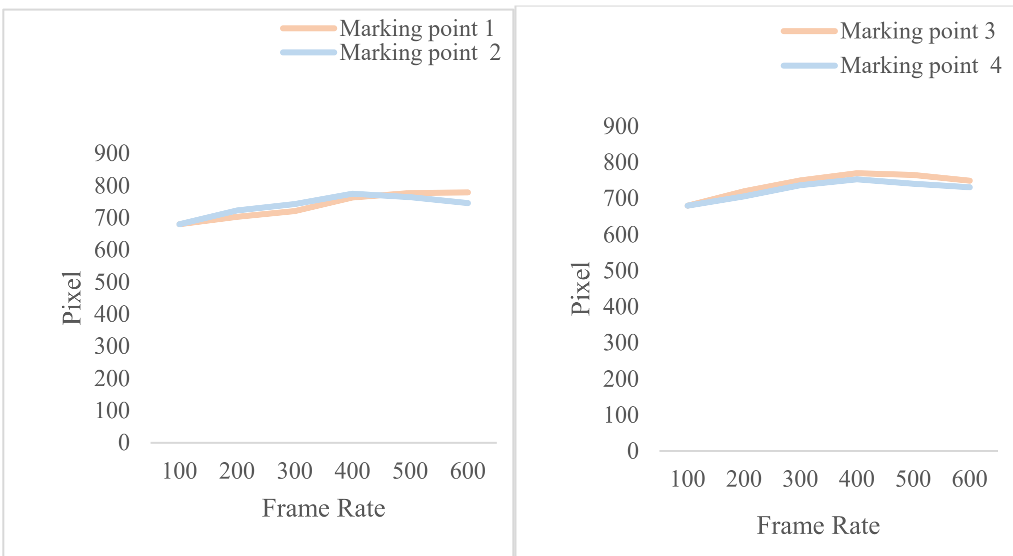

Figure 3: Marker point horizontal coordinate trajectory

According to the data in figure 3, the goodness of the ball throw is closely related to the serve, and this experiment explores the effect of raisings, swinging and hitting the ball on the serve in tennis serve

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respectively. It is generally believed that the height of the ball leaving the hand should be maintained at a ratio of 0.98 to the height of the body, and the instantaneous speed of the ball leaving the hand should reach 4.79 m/s. In layman's terms, the height of the ball after being thrown should be about the same as the height of the head, and if the height of the throw is too high or too low it will affect the effect of the serve.

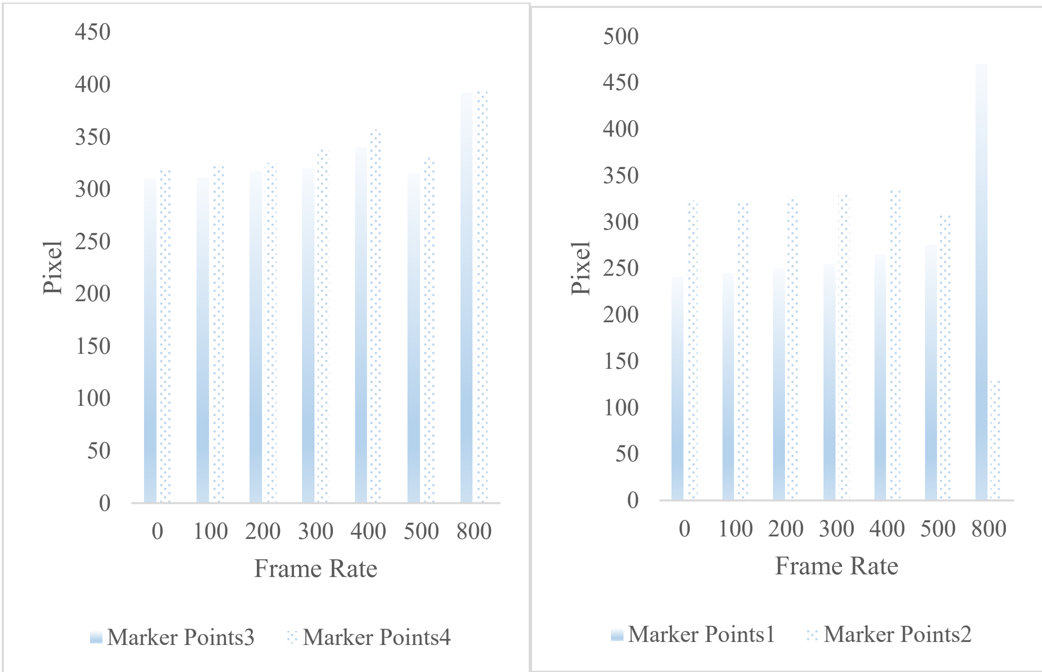

Figure 4: Marker point vertical coordinate trajectory

According to the data in figure 4, we need to form a good limb coordination posture in order to keep the ball at a good forward speed when we swing backwards on the serve, so that the hitting power can explode out in an instant, and at this time, the athletes' muscles are in an explosive contraction state, which can greatly exert the power.

5. Conclusions

The research topic of this paper is the study of tennis serve image path optimization using deep learning technology, which is the difficult and key point of using visual processing technology, in which we must detect the motion information of the key parts of the sports person for analysis, strengthen the serve training, send high quality balls, improve the match performance and take the initiative in the match. In this paper, the following work has been carried out: (1) How to capture images using deep learning technology for marking the key parts of the sportsperson, using hybrid Gaussian background for modeling and analysis, and avoiding the external environment to interfere with the environmental points of the marking points. (2) After the analysis of the motion trajectory, it is found that the arm has periodic mathematical characteristics in the process of serving, so the inherent characteristics of issuing the best hitting point are found in the experiment to improve the efficiency of serving. (3) In the process of conducting the experiment, it was found that in serving the ball, the offensive forward and backward draws were generally dominant, chipping was used the least, the serving style was relatively single, the forehand rate was used at a higher rate, but the backhand serve was more aggressive. In this paper, there are many shortcomings due to the actual conditions: (1) In the process of throwing the ball, we proposed to keep it within a ratio as much as possible, but if the ball is thrown too high or too low, what effect will it have on the serve is not explored, and the effect of serving too high or too low on the serve is also not mentioned. (2) In this paper, when conducting experiments, the data collection of key points is too redundant due to the technical constraints of marking points, and the data may not be the optimal solution.

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