Intelligent Recognition System for the Curves Trajectory and Track Capture Using Artificial Intelligence Technology

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Abstract. Aiming at the problem of large deviation of the recognition results of the traditional recognition system, this article carried out the design and research of the intelligent recognition system of the football curve ball movement trajectory. The hardware structure design includes the acceleration sensor selection, the angular motion detection device selection and the power supply circuit design, and the software structure design includes the motion trajectory data filtering processing and the football curve ball motion speed displacement recognition. Experiments show that, compared with the traditional system, the design system has a smaller deviation of the recognition results, significantly fewer recognition errors, and higher accuracy.

Keywords: Artificial intelligence technology, football training, motion trajectory capture, training assistance.

1. Introduction

When discussing oblique throwing motion in current college physics textbooks, mass points are the research objects, and the oblique throwing motion of rotating objects is rarely involved. In fact, the movement of rotating projectiles is a very common phenomenon, especially in ball sports, when the sphere is moving in the air, it is often accompanied by rotation, such as: football, table tennis, basketball and tennis. The rotation of the sphere itself will inevitably affect its trajectory, that is to say, in this case, the Magnus effect needs to be considered. When a cylinder rotates around its axis and a fluid flows in a direction perpendicular to the axis, it will receive a transverse force perpendicular to the direction of flow. The direction of the force always points from the direction of flow to the side opposite to the linear velocity on the surface of the cylinder. On the same side, this phenomenon is called the Magnus effect, and some scholars write it as the Magnus effect. At present, the system for recognizing motion trajectories mainly uses image gray information to segment images in video sequences [1]. But this kind of system ignores the original colour information of the image when recognizing the trajectory of the football curve ball, so the recognition results often have problems such as large errors and slow recognition speed. In response to the above problems, this paper proposes a new intelligent recognition system for the trajectory of the football curve by analysing the football curve ball movement.
2. Theoretical basis

2.1. Bernoulli principle
Bernoulli’s principle: The Swiss mathematician Daniel Bernoulli put forward the theorem that is now widely known. P is the pressure at a certain point in the airflow, $\rho$ is the airflow density, and V is the velocity at a certain point in the airflow.
\[ p + \frac{1}{2} \rho V^2 = C \] (1)

2.2. Magnus effect
According to Bernoulli’s principle, a ball with a curved trajectory must be rotated, and the lateral force that causes the trajectory of the ball to bend is generated by the rotation of the ball [2]. When rotating, it produces asymmetrical airflow, which produces lift or lateral force, which is perpendicular to the direction of the axis of rotation. It can be seen from Figure 1 that a rotating ball will deflect upward or laterally due to the difference in its axis of rotation.

![Football Bernoulli Principle](image)

**Figure 1.** Football Bernoulli Principle

2.3. Football force
The forces on a football are gravity, air resistance, and Magnus force due to the rotation of the ball. The Magnus force is just opposite to the direction of gravity, which is an upward force.

Some scholars pointed out that the aerodynamic force of a moving object is determined by the surface characteristics of the object itself, the area exposed to the air, the air velocity, and the pressure. They gave the formula for the force of any moving object in the air: $D$ is the air resistance, $F_{mag}$ is the Magnus force received, $C_d$ is the drag coefficient, $C_{mag}$ is the Magnus force coefficient, $A$ is the projected area of the sphere in the air, and $v$ is the relative flow velocity.
The drag coefficient and Magnus force coefficient of the sphere system

The drag coefficient is related to the density and speed of the airflow, and the resistance on the projection surface of the sphere. But for the same object, the difference in drag coefficient is directly related to the Reynolds number. Some scholars have found that the size of the Reynolds coefficient is related to the smoothness of the surface of the object and the speed of the object. Therefore, the faster the sphere, the more likely it is that the turbulence resistance is lower.

\( C_d \) decreases with the increase of Re. At the critical point, \( C_d \) will suddenly drop a lot. This phenomenon occurs because under critical conditions, the airflow will suddenly turn into turbulent flow, and the airflow streamlines will be separated, and the resistance will be greatly reduced in an instant.

Like the drag coefficient, the Magnus force coefficient of the sphere system is also related to the airflow density, speed, and the projected area of the object [3]. The theoretical Magnus force coefficient of a non-rotating ball is zero, so we only discuss the influence of the rotation of the ball on the Magnus force coefficient. Regarding a rotating ball, regardless of its rotation direction, it generates Magnus force, which changes the ball's trajectory and produces a curved ball.

The acceleration equation when the ball is flying in the air

When we consider gravity, Magnus force and air resistance, the vector equation of motion is:

\[
D = -\frac{1}{2} C_d \rho A \frac{v^2}{|v|} \frac{v}{|v|} \quad \text{(2)}
\]

\[
F_{mag} = \frac{1}{2} C_{mag} \rho A \frac{|\omega \times v|}{|\omega \times v|} \quad \text{(3)}
\]

2.4. The drag coefficient and Magnus force coefficient of the sphere system

2.5. The acceleration equation when the ball is flying in the air

When we consider gravity, Magnus force and air resistance, the vector equation of motion is:

\[
a = \frac{F_{mag}}{m} + \frac{D}{m} + g \quad \text{(4)}
\]

Bring in \( F_{mag} \) and D to get:

\[
a = \frac{1}{2} \frac{C_{mag} \rho A |v|^2}{m} \frac{|\omega \times v|}{|\omega \times v|} \quad \frac{1}{2} \frac{C_d \rho A |v|^2}{|v|} + g \quad \text{(5)}
\]

Among them, \( a \) is the acceleration of the sphere movement, \( m \) is the mass of the sphere, and \( g \) is the acceleration due to gravity. The equation for the acceleration of the sphere flying in the air has been given. For a determined sphere, due to the uncertainty of \( \rho \) in the environment and the uncertainty of the two parameters \( C_{mag}, C_d \) and, we cannot give a simpler formula Equation. Under the existing conditions, the author cannot give more explanations and descriptions about this equation [4]. When there are better conditions in the future, I hope that a computer can be used to simulate this equation and give more graphical explanations.

3. Design of intelligent capture system for football trajectory

3.1. System hardware design

3.1.1. Selection of acceleration sensor. Because the arc of football is a three-dimensional moving object in space, and athletes usually participate in the process of football, its moving range is small. According to this feature, this article chooses KSD-2563 model acceleration sensor.
3.1.2. Selection of angular motion detection device. The SJDA-25542 angular motion detection device can provide the system with digitally adjustable sensor data through a simple serial interface, and the serial interface can provide access to the angular motion detection device, temperature, and power supply voltage measurement [5]. According to the vibration coupling of the angular motion detection device in the driving mode, by detecting the displacement or corresponding change of the angular motion detection device in the detection mode, it is obtained that the angle of the football curve ball is large.

3.1.3. Power circuit design. The mobile terminal of the system in this paper uses a 4.0V button battery to provide power, and the base station uses a 4C external power supply. The operating voltage of the above acceleration sensor device during operation is 3.5V, and the operating voltage of the angular motion detection device during exercise is 4.5V. According to the system operation needs of this article, the regulated power supply model is designed to meet the working voltage of different hardware devices. Figure 2 is a schematic diagram of the connection of the system power circuit in this article.

![Figure 2. Schematic diagram of the system power circuit connection in this article](image)

3.2. System software design
Input the speed and displacement data recognized by the system into MATLAB software to complete the drawing of the three-dimensional trajectory of the football curve ball, and realize the intelligent recognition of its motion trajectory.

4. Application of the model to specific phenomena
According to international standards, we take the parameters of football as shown in Table 1.

| Football parameters | Diameter | Quality | Goal specifications | Distance from penalty area line to goal line | Air density |
|---------------------|----------|---------|---------------------|--------------------------------------------|-------------|
| 69cm                | 430g     | 7.32m×2.44m | 16.5m               | 1.25kg/cubic meter                          |

Brazilian player Didi invented the elevator ball (also known as the deciduous ball), and the representatives of the deciduous ball in today's football include Pirlo, Cristiano Ronaldo and so on. This article will take Cristiano Ronaldo's elevator ball as an example to study the trajectory of the elevator ball and the reason why the ball plunges before it falls into the goal. I use the free kick mode in the game of live football to help us build an intuitive model. Figure 3 is a computer simulation of Cristiano Ronaldo's free kick situation.
According to Cristiano Ronaldo's free kick style, we chose his best 23m distance to study his free kick trajectory. The deciduous ball in this way has almost no lateral rotation and has a certain amount of external rotation [6]. No side spin means that the ball will not have a lateral arc. We simplified the flight trajectory of his entire ball into a plane motion (Figure 4).

\[ D = -0.13 \rho A |v|^2 \frac{v}{|v|} \quad (6) \]

In the formula (3), \( R \) is the radius \( C_{mag} = \frac{2\omega R}{v} \) of the sphere, so the formula (3) is simplified to:
\[ F_{\text{mag}} = \frac{\omega R}{v} \rho A |v|^2 \frac{\omega \times v}{|\omega \times v|} \]  

We only study the two-dimensional motion, decompose the speed in the x and y directions, and only consider the angular velocity of the z axis:

\[ v = \sqrt{v_x^2 + v_y^2} \]
\[ \omega = \omega_z \]  

(8)

Various data show that the speed of a very high-speed free kick can be as high as 120km/h, and in some cases, it can even reach 200km/h. We assume that Cristiano Ronaldo's ball speed is 100km/h, that is, the average speed is 27m/s. Due to the characteristics of Cristiano Ronaldo's free kick, we assume that it is non-spinning, that is \( \omega = 0 \). Under such a setting, we turn Eq. (5) into its simplest form:

\[ a = -0.13 \frac{\rho A |v|^2}{m} \frac{v}{|v|} + g \]  

(9)

Bring in \( \rho, A, m \) to get

\[ a \approx -0.05 |v| v + g \]  

(10)

Solve for both x and y directions

\[ \frac{dv_x}{dt} = 0.05v_x \sqrt{v_x^2 + v_y^2} \]  

(11)

\[ \frac{dv_y}{dt} = 0.05v_y \sqrt{v_x^2 + v_y^2} + g \]  

(12)

There is no analytical solution to this equation, so I use computer graphics. Assuming that the initial speed of the ball is 30m/s, since the angle of the foot cannot be determined, the computer simulates the possible trajectory of different angles of the foot under this equation, as shown in Figure 5 below.

![Figure 5. Computer simulation of the trajectory under different angles](image-url)
The above picture is a simulation of the trajectory when the ball exit angle is 30 degrees. From the picture, it can be seen that the ball falls to the lowest point approximately at 23m, which can just fall into the goal and successfully bypass the wall. The trajectory is approximately in line with the actual situation. It can be considered that the given equations (11) and (12) are referenced to a certain extent. However, the Magnus force is not used in this discussion, which is the neglected force among the three forces. Due to the characteristics of the elevator ball, the Magnus force is very small due to the small rotation, which does not have much influence on the discussion of the trajectory.

5. Conclusion
In this paper, combining the law of football curve ball movement, a new intelligent recognition system of football curve ball movement trajectory is proposed. While realizing the movement trajectory recognition, the relevant software and hardware are explained in detail, and the performance of the system is proved through experiments. In the follow-up research, the system's recognition accuracy will be further studied, so as to realize the centimetre or even millimetre-level recognition of the football curve ball movement trajectory.

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