

## Retraction

# Retracted: Design and Research on the Foul Detector of a Long Jump Jumping Line Based on a Vision Sensor

### Journal of Sensors

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### References

- [1] D. Yang and X. Bian, "Design and Research on the Foul Detector of a Long Jump Jumping Line Based on a Vision Sensor," *Journal of Sensors*, vol. 2021, Article ID 8364194, 17 pages, 2021.

## Research Article

# Design and Research on the Foul Detector of a Long Jump Jumping Line Based on a Vision Sensor

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Long jump is one of the important events of modern track and field sports, and it is also one of the regular events of major events. Due to the complexity and technicality of the project, the determination of the results in a formal competition is also very complicated. It is easy for athletes to invalidate their results due to fouls by stepping on the jump line. Therefore, it is very necessary to detect fouls. This paper uses a visual sensor technology to design and develop a foul detector for the situation of athletes stepping on the jump line in a long jump, which can detect fouls well. In the formal competition process, because the long jump time is relatively short, the referee is interfered by many factors and it is easy to misread the movements of the athletes and cause misjudgment. Therefore, on this basis, in order to improve the fairness of the game and create a good competition environment, the design is designed. The long jump stepping line foul detector is studied, and the visual sensor technology is used, which can judge the long jump stepping fouls during the long jump based on the feedback data.

## 1. Introduction

Long jump is one of the important events of modern track and field sports. It is based on the life skills acquired by humans when they cross rivers and ditches when hunting or evading beasts. It has gradually evolved into a means of military training, and it is still maintained today.

*1.1. For Spread.* Long jump was included in the Olympic Games track and field events more than 100 years ago and played an indispensable role in the track and field events. When track and field was officially included in the official games of the Games, long jump was one of the participating events. As people pay more and more attention to the Olympic Games, various sports events are becoming more and more popular, which also reflects the characteristics of people's pursuit of faster, stronger, and faster sports. With the continuous improvement of modern athletes' technology, the overall level of the long jump in the world continues to improve but the resulting judgment issues have also

attracted people's attention. Whether the athletes foul in the game also mainly depends on the judgment of the referee.

With the development of science and technology, there are more and more modern-related papers on long jump and there are not a few researches on long jump using different techniques but there is still a lack of research on fouls. Nowadays, the level of long jump is getting higher and higher and the performance of each country is also improving, leading to more and more perfect rules. At this time, there will be certain errors in the judgement of the game by the naked eye of the referee, which may be caused by various reasons.

*1.2. Misjudgment by the Referee.* On this basis, the latest visual sensor technology is used to monitor the athletes' long-jump stepping fouls and provide real-time feedback. The researched and developed long-jumping line foul detector can be well applied in various competitions.

The combination of vision sensor technology and long jump can use new technologies to discover subtleties that were previously irrecoverable [1, 2]. With the development of modern track and field events, the techniques and rules of long jump are becoming more and more perfect [3]. The rules in modern long jump competitions are gradually increasing, making it easy for referees to make judgments based on the results they see, leading to the possibility of misjudgment [4–6]. One of the main tasks of long jump training is to allow athletes to master certain project rules and to use and create flexibly on this basis to avoid fouls caused by incorrect posture [7, 8]. From the perspective of traditional sports training models in the past, coaches' sports teaching tends to stay more at the level of theoretical and empirical teaching. This teaching method has fallen behind in this era. Athletes cannot see their own problems based on accurate data and do not have timely feedback to update themselves [9, 10]. The application of visual sensor technology in the long jump event allows athletes to see their own problems and improve them [11]. Moreover, with the help of visual sensor technology, coaches can show athletes some of the attention points and skills in the long jump more vividly to avoid the next foul [12–14]. With the help of visual sensor technology, coaches can teach athletes some long jump essentials by looping video images, allowing athletes to understand long jump postures and techniques from different directions and angles [15–18]. Coaches should be good at creating real and complex scenes, pay attention to the use of modern information technology, and integrate visual sensor technology, Internet of things, smart watches, wireless communications, and other information technology methods with the teaching of sports and health courses [19, 20]. The moving object detection and tracking algorithm is an important research field of machine vision. However, in most detection and tracking methods based on background extraction, the visual sensor needs to be fixed, which will greatly limit the flexibility of the system. In order to reduce the system's dependence on the background model and improve the system's anti-interference ability, the tracking ability of the visual sensor has a strong guiding significance for the action norms in the course of physical education. This has greatly improved the teaching effect of the long jump [21–23]. At the same time, through the visual sensor technology, the athletes' learning interest and enthusiasm will be greatly improved and unnecessary mistakes will be avoided [24]. Pan believes that traditional teaching aids still play an irreplaceable role in the teaching of track and field technical courses [25]. Zhang put forward a set of practical and effective real-time rapid diagnosis and feedback systems for digital-physical education training for the current situation that China's higher physical education colleges rarely use modern teaching methods in track and field technical classes [26]. Moreover, the use of the system for teaching track and field technicians can also help young teachers improve their teaching ability in explaining, demonstrating, and organizing teaching, to help young teachers quickly improve their teaching level [27]. The other two training centers of the US Olympic Committee are located in the first La Vista and Lake Placid in California, which are also

equipped with the same advanced equipment [28]. American players who participated in the 2004 Olympic Games generally adopted digital training. Sensors, video recordings, and notebook computers have become “three big pieces” essential for American Olympic athletes. Now, the \$1,500 laptop has indeed become a must for American athletes. The American team recorded hundreds of hours of tests and video recordings with laptops. By comparing the video of two athletes together or one on top of the other, athletes and coaches can get a more intuitive effect [29].

This article integrates the vision sensor technology into the foul detection of long jump. This technology can also be used in normal training. After the training is completed, the athlete can check whether he has violated the rules by viewing the software. The coach can show prerecorded demonstration actions, graphical decomposition, and text interpretation on the screen to learn before the athletes compete. Studies have shown that the use of visual sensor technology can greatly reduce the probability of athletes fouling the rules and can well correct athletes' competition movements [30, 31].

*1.3. Theoretical Basis of Vision Sensors.* The vision sensor is the direct source of information for the entire machine vision system [32, 33]. It is mainly composed of one or two graphic sensors, sometimes with light projectors and other auxiliary equipment [34]. The main function of the vision sensor is to obtain enough original images to be processed by the machine vision system. The image sensor can use a laser scanner, a linear and area CCD camera, or a TV camera or the latest digital camera [35]. Vision sensor refers to an instrument that uses optical elements and imaging devices to obtain image information of the external environment. Image resolution is usually used to describe the performance of the vision sensor. The accuracy of the vision sensor is not only related to the resolution but also related to the detection distance of the measured object. The farther the measured object is, the worse its absolute position accuracy is [36]. The key part of the vision sensor in the vision measurement system is the first step of the whole project. Figure 1 shows the working principle diagram of the vision measurement system.

In order to describe the imaging geometric relationship of the vision measurement system, a small hole model, which is widely used in vision measurement, is also called a linear model. It refers to the camera model whose predetermined scene is projected onto the imaging plane through the center point of the camera's optical axis. In the Cartesian space of the camera, suppose that the coordinates of the scene point  $P_1$  are  $(x_1, y_1, z_1)$  and the coordinates of the imaging point  $P_1$  of  $S_2$  on the imaging plane  $P_2$  are  $(x_2, y_2, z_2)$ ; then,

$$\begin{aligned} \frac{x_1}{z_1} &= \frac{x_2}{z_2} = \frac{x_2}{f}, \\ \frac{y_1}{z_1} &= \frac{y_2}{z_2} = \frac{y_2}{f}, \end{aligned} \quad (1)$$

where  $f$  is the specific focal length of the camera.

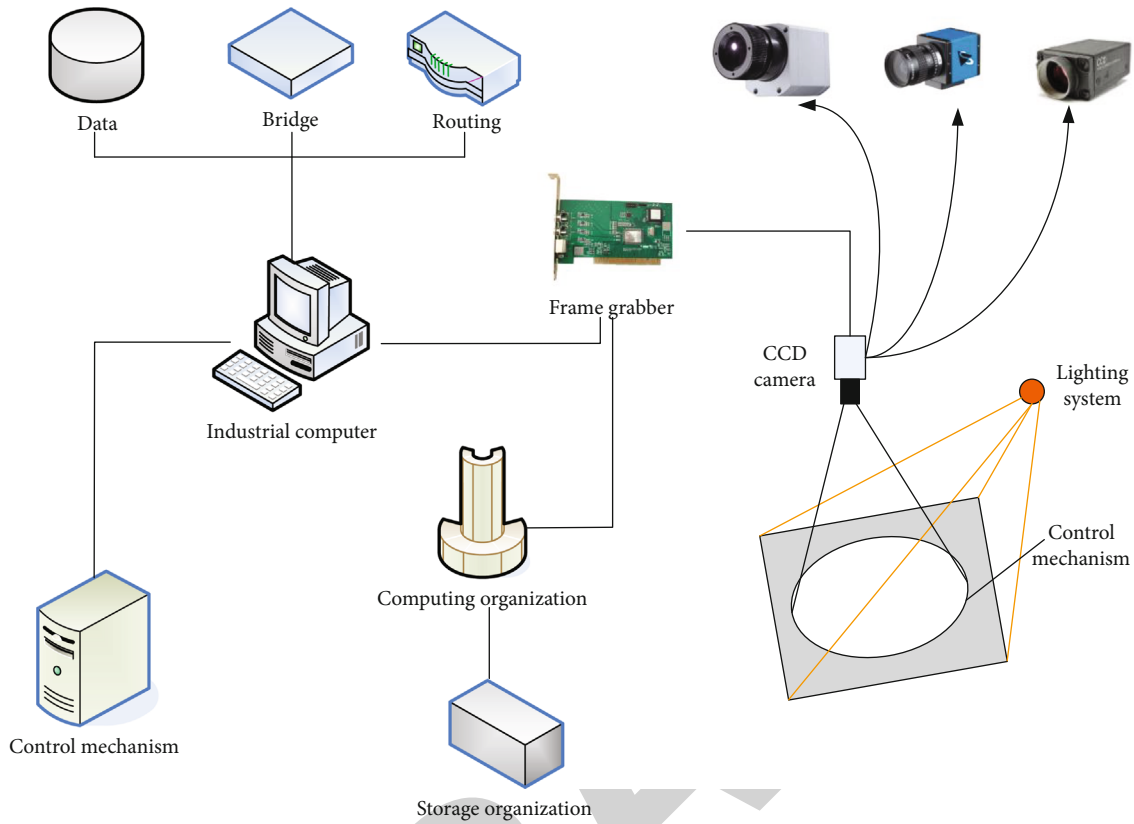


FIGURE 1: The working principle diagram of the vision measurement system.

The entire process of the long jump movement is recorded in detail by the camera and fed back to the background database. According to the detailed description of the camera coordinate system, any point  $P_1$  in the entire space state can be displayed in a three-dimensional coordinate system, point  $P_1$ . Through the small hole model projection, the coordinates of the camera imaging plane can be expressed, which can be obtained by formula (1) as follows:

$$\begin{aligned} \frac{x}{f} &= \frac{x_c}{z_c}, \\ \frac{y}{f} &= \frac{y_c}{z_c}. \end{aligned} \quad (2)$$

Formula (2) can be transformed into the expression of the matrix form as

$$z_c \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix}. \quad (3)$$

Combining the above formulas, we can finally get the correlation conversion  $z_c$  formula between the image coordinate system and the camera coordinate system:

$$z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix}. \quad (4)$$

It is also available as follows:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} k_x & 0 & u_0 \\ 0 & k_y & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{x_c}{z_c} \\ \frac{y_c}{z_c} \\ 1 \end{bmatrix}. \quad (5)$$

The rotation matrix  $R$  and the translation vector  $P$  are used to express the relationship between the camera coordinate systems. For any point in the space coordinates, the corresponding relationship between them can be expressed by the following formula:

$$\begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = \begin{bmatrix} R & p \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix}. \quad (6)$$

In the camera's coordinate system, the coordinate system of a certain point can be described in detail through the camera's external parameter model.

In the calibration method of the internal and external parameters of the linear model camera, the basic principle is to collect a stereo image  $k_x$  with predictive feature points through the camera and the feature points are extracted from the image coordinates  $R$  and the three-dimensional space coordinate system  $y$  to establish an equation; assuming the measured that the position of the point in the coordinate system is known, then,

$$z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} k_x & 0 & u_0 & 0 \\ 0 & k_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & p \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = M \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix}. \quad (7)$$

The vision sensor has thousands of pixels that capture light from an entire image. The clarity and fineness of an image is usually measured by resolution, expressed in the number of pixels [37]. Therefore, the sensor can observe a very delicate target image regardless of the distance to the target by a few meters or a few centimeters. After capturing the image, the vision sensor compares it with the reference image stored in the memory for analysis. For example, if the vision sensor is set to identify machine parts with eight bolts correctly inserted, the sensor knows that parts with only seven bolts should be rejected or parts with misaligned bolts [38]. In addition, no matter where the machine part is located in the field of view, whether the part is rotated within 360 degrees, the vision sensor can make a judgment. Figure 2 shows the basic schematic diagram of the visual sensor, which is also widely used in real life.

For different automobile assembly plants, the visual sensor in this field is mainly responsible for checking whether the rubber beads of the relevant door frame operated by the robot meet the standards and whether they maintain the correct width; in various pharmaceutical packaging production lines, the visual sensor can check whether there are any damages, missing tablets, etc. in the packaging of aspirin medicines. The application field of the vision sensor also includes a variety of ordinary packaging manufacturers. Among these manufacturers, the vision sensor can check whether the relevant position is affixed with a standard packaging label. Research on the algorithm of fusion of visual sensor based on nonlinear optimization with imu, and apply it in specific experiments. The fusion methods

between them include filtering methods and tight coupling and loose coupling. Nonlinear optimization also has tight coupling. There are two types of coupling and loose coupling, which only optimize the visual effect visually:

$$E_{\text{proj}}(j) = \rho((x - \pi(X_C))^T \sum_X (x - \pi(X_C))). \quad (8)$$

The reprojection time error term will be generated when the imu algorithm is fused with the vision sensor:

$$\theta = \arg \min_{\theta} \left( \sum E_{\text{proj}}(j) + E_{\text{IMU}}(i, j) \right). \quad (9)$$

Use a certain process to connect all links, including linear regression models and analysis of variance models. The number of linear transformations is usually in the case of a normal distribution. The imu time error term is

$$J(X) = \sum_{i=1}^I \sum_{k=1}^K \sum_{j \in J(i,k)} e_r^{i,j,kT} W_r^{i,j,k} e_r^{i,j,k} + \sum_{k=1}^{K-1} e_s^{kT} W_s^k e_s^k. \quad (10)$$

The observations of the two sensors are independent of each other, and the random errors during observation form a multiple linear relationship, which is obtained by standardizing the cost function and the mean error, where  $e_s^k$  is

$$\begin{aligned} e_r &= \log \left( \left( \Delta R_{ij} \exp \left( J_{\Delta R}^g b_{ij}^g \right) \right)^T R_{BW}^i R_{WB}^j \right), \\ e_v &= R_{BW}^i \left( w v_B^j - w v_B^i - g w \Delta t_{ij} \right) \\ &\quad - \left( \Delta v_{ij} + J g \Delta v b_{ij}^g + J a \Delta v b_{ij}^a \right), \\ e_p &= R_{BW}^i \left( w P_B^j - w P_B^i - w v_B^i \Delta t_{ij} - \frac{1}{2} g w \Delta t_{ij}^2 \right) \\ &\quad - \left( \Delta p_{ij} + J_{\Delta p}^a b_{ij}^a \right), \\ e_b &= b^j - b^i. \end{aligned} \quad (11)$$

The above formula has three important variables,  $R$ ,  $V$ , and  $P$ , and the deviation variable  $b$  can be set to 0 during initialization, so the calculation will not be very troublesome and the formula for weight is as follows:

$$\begin{aligned} W_s^K &= \left( \frac{\partial e_s^K}{\partial \delta \hat{\chi}_R^{k+1}} P \left( \delta \hat{\chi}_R^{k+1} | X_R^k, Z_s^K \right) \frac{\partial e_s^K}{\partial \delta \hat{\chi}_R^{k+1}} \right)^{-1}, \\ \frac{\partial e_s^K}{\partial \delta \hat{\chi}_R^{k+1}} &= \begin{bmatrix} I_3 & O_{3 \times 3} & O_{3 \times 9} \\ O_{3 \times 3} & 0 & O_{3 \times 9} \\ O_{9 \times 3} & O_{9 \times 3} & I_9 \end{bmatrix}. \end{aligned} \quad (12)$$

Among them are the covariance matrix of  $R$ ,  $P$ ,  $V$ , and  $b$ .

*1.4. Theoretical Basis of Long Jump.* Long jump, also known as "fast long jump," is one of the modern track and field

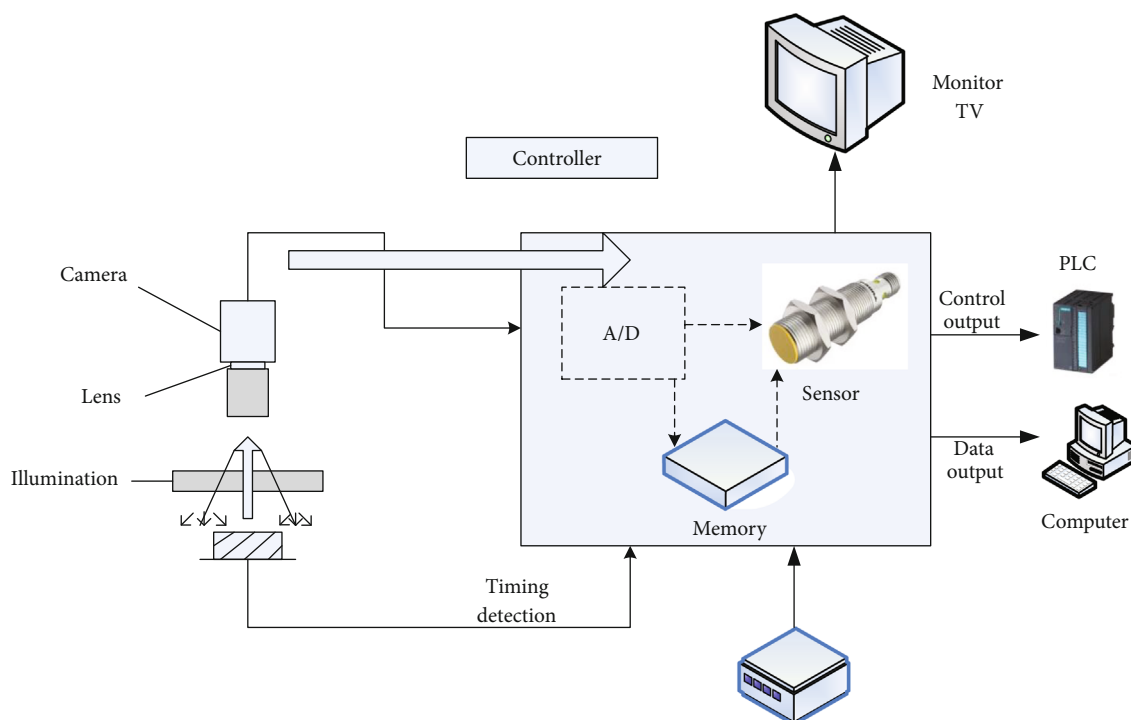


FIGURE 2: Basic schematic diagram of the vision sensor.

sports. This is a track and field event that can run in a straight line on the approach platform. Start with a sprint at the beginning, and finally, fall into the bunker with your foot. In the game, the ranking is determined by the distance of the jump. Long jump was originally the ability of humans to find food and escape from wild animals. Later, the conditions and methods for recruiting and training soldiers were formulated. In the ancient Greek Olympics, long jump was one of the traditional events. In the continuous development of the track for hundreds of years, people are pursuing “higher, faster, and stronger” and the limits of mankind have been broken time and time again. Although mankind continues to push boundaries, more and more experts and scholars around the world want to use technology to discover the limits of mankind and more and more sports researchers want to use the technology to further improve related technologies. Athletes find the best training methods and methods to help them improve the quality of training. The long jump facilities include a running platform, a take-off board, and a landing area. The landing area is usually located on a straight road. There are landing areas at both ends of the two adjacent runways, which ensures that the race can be carried out in both directions. Figure 3 shows a schematic diagram of the long jump event in the official competition.

There are many rules in the long jump competition. The score calculation is based on the judgment of the referee. If the athlete encounters an obstacle during the jump, the referee can judge the obstacle and give them a second chance to jump. Athletes can leave the playing field during the game. However, it must be approved by the referee and accompanied by the referee. Athletes cannot accept assis-

tance during the game. Unless it is a medical examination by a doctor or other conversations or exchanges with people outside the court, the referee may exceed the game time limit and do not follow the rules and decide the gap between the trial jumps. In the long jump competition, there are many cases of foul evaluation, for example, the athletes touch any part of the body before the line before the jump, takeoff at places other than the two ends of the takeoff board, and use anything during the run up and during the jump. During somersault poses, the referee does a trial jump without notifying the athlete that the trial jump is allowed or misses the trial jump sequence for no reason, etc.; it is a foul.

### 1.5. Design of a Foul Detector for Stepping on Jumping Lines in Long Jump

**1.5.1. Transmitter Principle.** The transmitter emits a high-speed electron beam composed of an actuator, a working medium and a tuning channel. The stimulus produces more stimulating radiation than the stimulus absorbs. The working medium that causes population reversal has the characteristics of the diffusion energy level, which can enhance cavity resonance and generate positive feedback to form excitation and maintenance. Figure 4 shows the detailed design of the transmitter principle. The main component of the transmitter is a low-power luminous tube, which converts the light emitted by the light source device into modulated light, which can be emitted from a long distance. Provide high pulse current. The maximum value can be given by the average pulse current corresponding to DC of the low-power LED. And receiving high maximum radiation

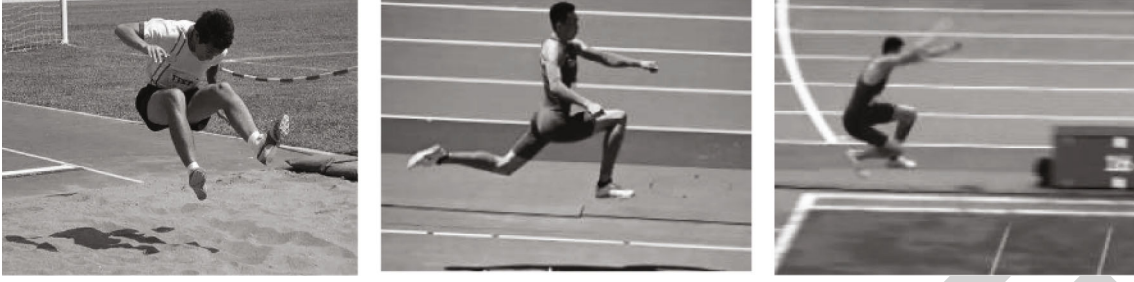


FIGURE 3: Schematic diagram of long jump athletes' actions.

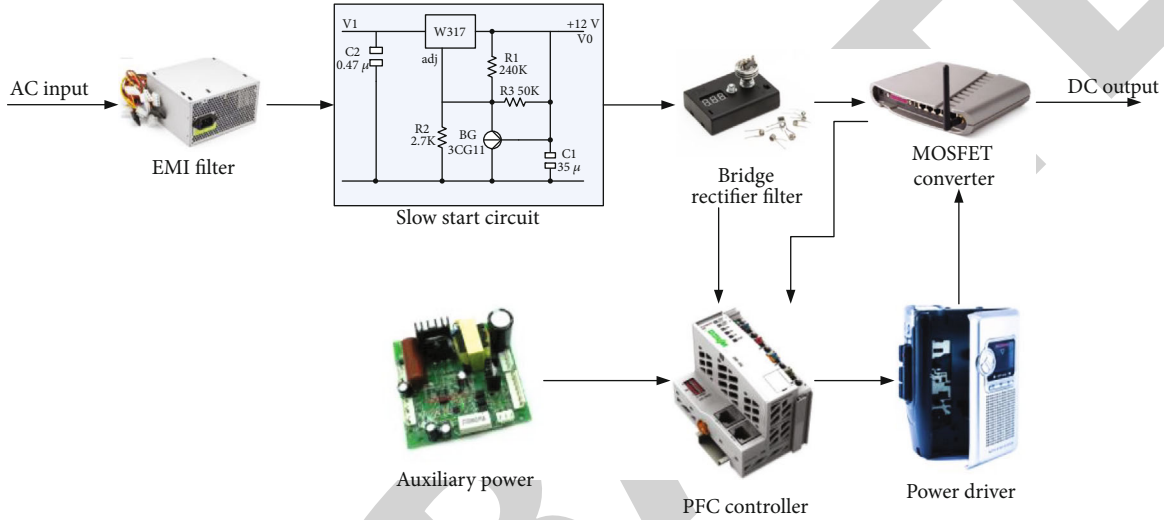


FIGURE 4: The detailed design of the transmitter principle.

power, effective transmission distance and maximum pulse power are positively correlated.

When the output resistance of the current source is large enough, the voltage induced by the magnetic field coupling into the wire loop will not have a significant effect, because the current caused by the interference source is very small, and the interference can be reduced by using twisted pair wires in general. Each single display reading device or recording device can be switched between different channels with unequal wire lengths, and there is no difference in accuracy due to unequal wire lengths.

The relationship between peak pulse current and charging DC is

$$I_p = I_M \times \frac{T_O}{t_d}. \quad (13)$$

Among them,  $I_p$  is used to describe the peak pulse current and  $I_M$  is used to describe the maximum current that can be withstood in the working state.  $T_O$  is used to describe the operating time of the oscillation, and  $t_d$  is used to describe the high level of the pulse width. The transmitter power increases correspondingly, the maximum current  $I_p$  also increases, and  $I_M$  does not change. The maximum pulse current can be increased. The designed sensor control circuit ensures that the pulse peak amplitude level is minimized.

The low-frequency antenna is composed of resistors, capacitors, and inductors connected in parallel. In order to achieve the best low-frequency receiving sensitivity, the simple harmonic motion of the inductors and capacitors must have a frequency of 125 kHz. The calculation formula is

$$f_c = (2\pi\sqrt{LC})^{-1}. \quad (14)$$

The corresponding capacitance value can be derived by formula (14):

$$C = \frac{(1/2\pi f_c)^2}{L}. \quad (15)$$

The parallel resistance  $R$  mainly reduces the circuit quality factor of the LCD simple harmonic circuit to  $Q$ , which achieves a sufficient bandwidth of 7.8 kHz. The quality factor of the simple harmonic circuit is

$$R = \frac{f_c}{BW} \times XL. \quad (16)$$

**1.5.2. Receiver Principle.** The receiver has high light transmission efficiency and low power consumption. The receiver collects the signal sent by the transmitter and amplifies it. Filter out useless bands. And send the necessary signals to



FIGURE 5: Detailed design diagram of the receiver principle.

the alarm interface circuit. In order to improve the detection accuracy of long jump and jumper foul detectors, 2CU diodes are used as photoelectric conversion receivers. Figure 5 shows the detailed design of the receiver principle, which is widely used in our daily life for information transmission.

In the receiver, the signal can be demodulated to the baseband by removing the high-frequency signal and make full use of the orthogonality of the sinusoidal signal to reduce the noise in the received signal. The noise power spectrum is wider than the signal power spectrum. Lower external noise. By sampling the signal points back to find the amplitude and time-discrete signals and using the best decision criterion to get the lowest bit error rate, the description of the received signal is

$$r(t) = s_m(t) + n(t), \quad 0 \leq t \leq T, \quad (17)$$

where  $n(t)$  represents the sample function of additive white Gaussian noise with high power spectral density.

$$\begin{aligned} s_m(t) &= \text{Re} [(A_{mc} + jA_{ms})g(t) \exp j(2\pi f_c t)], \\ s_n(t) &= A_{mc}g(t) \cos(2\pi f_c t) - A_{ms}g(t) \sin(2\pi f_c t). \end{aligned} \quad (18)$$

The position of the signal in the plane can be determined to a large extent, and the transmitted signal can be written as

$$\begin{aligned} s(t) &= \text{Re} [(x(t) + jy(t)) \exp(j2\pi f_c t)], \\ s(z) &= x(z) \cos(2\pi f_c t) - y(z) \sin(2\pi f_c t) \cos(2\pi f_c t). \end{aligned} \quad (19)$$

Figure 6 shows a schematic diagram of the transmitter circuit and receiver circuit in the detector. The main job of

the transmitter circuit in the instrument is to source the operating current, which can emit red light that is invisible to the human eye. The signal is transmitted to the receiver to determine whether the athlete crosses the line during the long jump and stepping during the long jump. The operating voltage in the transmitter's circuit is DC +5 V, and the operating current is 10 mA. The receiver is used to collect the signals transmitted by the transmitter and process the collected signals and can drive the circuit interface of the sound and light alarm to alarm and transmit relevant signals to notify the personnel.

**1.5.3. Integrated Voltage Regulator Circuit and Sound and Light Alarm Circuit.** LT1965 is a low-noise, low-dropout linear regulator. It can generate 1.1A output current and 310 mV voltage difference. The working current is 500 mA, which can be reduced to below 1 mA in OFF mode. The current stagnation can be effectively managed. As the voltage decreases, the price of LT1965 remains unchanged. The output voltage fluctuation range is 1.05~18.2 V. The LT1965 controller can run smoothly with an output capacitance lower than 10 mV, and the internal protection circuit is protected by reverse and reverse battery connections. If 5 V DC is provided to the circuit, protect and suppress components. After activating the DC filter through E4, the regulator is used for 3.3 V DC output. The audible and visual alarm is to pass the collected information to the athletes in a very obvious way. It can easily find out if the level signal is violated. When the level signal generated by the receiving circuit changes from high to low, it will drive the visual and audible alarm circuit to generate. The corresponding alarm reminds the athletes that they have crossed the line during the long jump. When there is no signal on the receiver, the relay is closed and activated. En turns on the voltage circuit and executes the sound and light alarm circuit IC9561 to



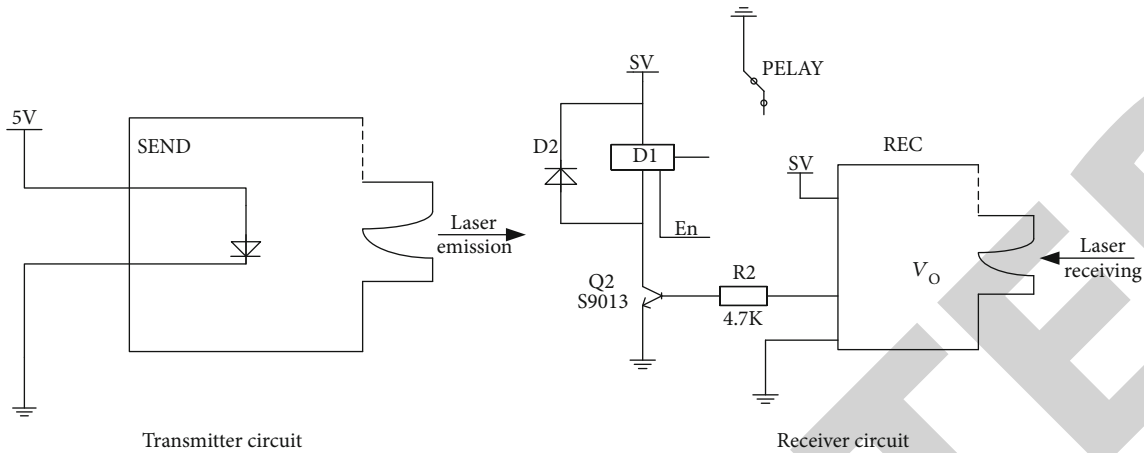


FIGURE 6: Schematic diagram of transmitter circuit and receiver circuit.

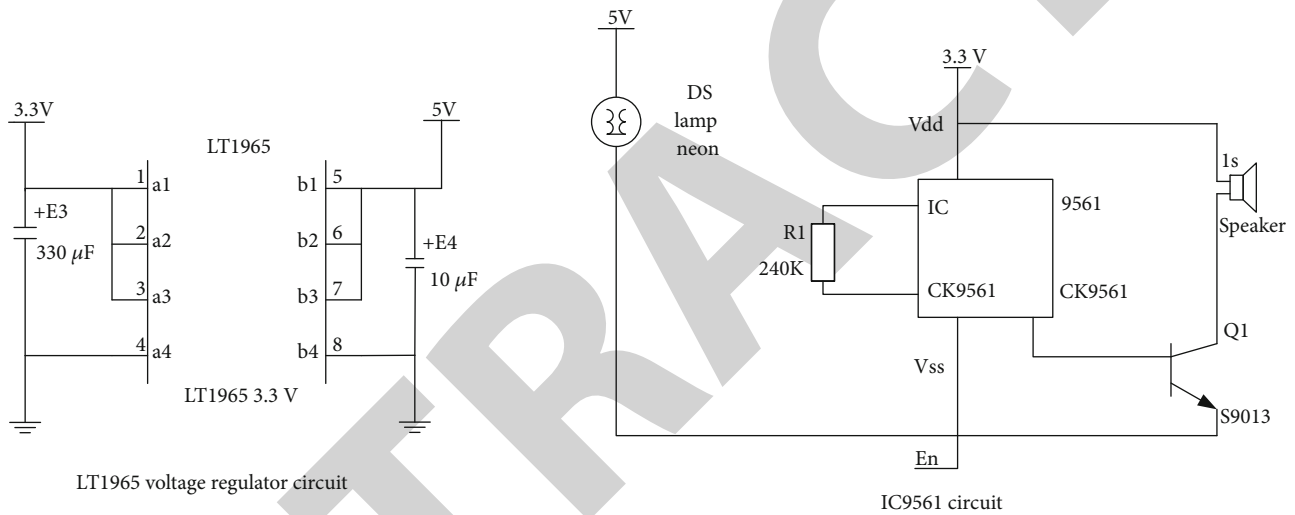


FIGURE 7: LT1965 voltage regulator circuit and IC9561 circuit.

output and amplify the alarm signal and output the alarm signal through the speaker. At this time, the LAMP power supply is turned on and the alarm light is on and it will be sent out. Figure 7 shows the LT1965 voltage regulator circuit and IC9561 circuit.

## 1.6. Experiments

**1.6.1. Experimental Object.** The subjects of this study were 50 students from the College of Physical Education, and the teaching content was a long jump. The research time was from September 2017 to June 2018; the duration is 1 school year. According to the middle school physical education syllabus, they were divided into an experimental group and a control group by random allocation method. The experimental group uses multimedia teaching methods, while the control group uses traditional teaching methods. Both groups of students were taught by the same teacher to minimize the error of the experiment. After the end of the lecture, the two groups of students were tested for technical compliance [38] and the experimental data were compared and analyzed. Considering that other factors will affect the

results of the experiment, both groups of students are conducting teaching experiments without prior notice. Before the experiment, the two groups of students were tested for physical education. The results are shown in Table 1. Judging from the test results, the two groups of students had no significant differences in physical indicators.

**1.6.2. Experimental Design and Implementation.** The first stage of training and teaching was using multimedia teaching to teach each session for 15 minutes; the main way through multimedia display is wall charts, graphics, animation Flash, and video as the main content. First of all, let students watch the wall charts and illustrations so that students can intuitively understand the most essential rules of long jump technical movements. It can express the meaning that the text information cannot express, so that the technical movements taught in the long jump teaching form the correct appearance in the students' brains, so that the teaching content is not boring. Secondly, adding multimedia elements such as animation Flash or video in the teaching demonstration makes the teaching class more vivid and interesting. In

TABLE 1: Student physical fitness test and test results.

Test name	Group	Number	Average value	Standard deviation	P
Standing long jump (cm)	Control group	25	270	6.33	$P > 0.05$
	Experience group	25	271	7.51	
Longitudinal picking height (cm)	Control group	25	49	3.91	$P > 0.05$
	Experience group	25	50	4.16	
Achievement	Control group	25	5.11	0.13	$P > 0.05$
	Experience group	25	5.13	0.19	

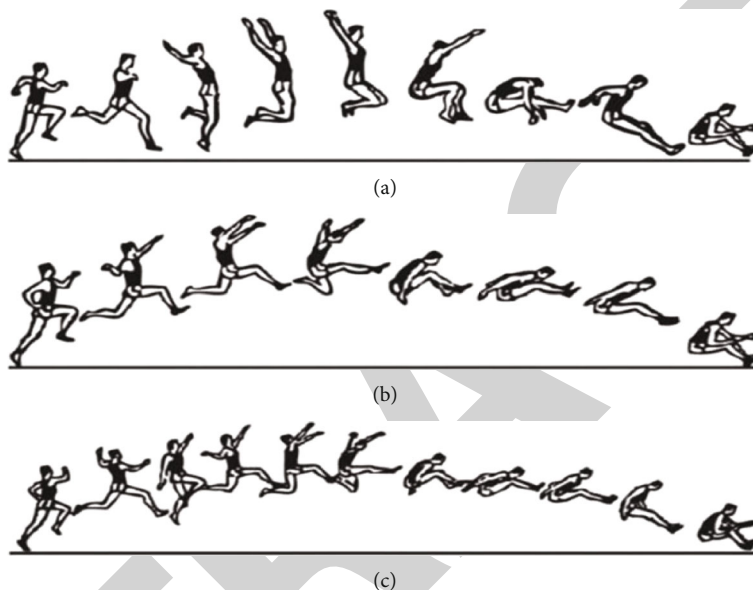


FIGURE 8: Analysis of multimedia long jump action.

the long jump technical teaching, there are many explanations of actions that can not be elaborated and expressed in language or even expressed. The meaning will have some error with the original meaning, or the students may understand the error, etc.; the use of multimedia teaching courseware can compensate for the shortcomings of traditional teaching [39]; It can more accurately and intuitively explain the difficulty and difficult points of long jump technical movements, easy-to-make mistakes, and other problems, so that students can grasp the basic technical essentials more quickly.

The second stage of training and teaching, using multimedia teaching to teach each session for 30 minutes, the main teaching content at this stage is the use of long jump technology.

**1.7. Multimedia Courseware Design.** Figure 8 shows the long-distance motion analysis diagram made by multimedia technology, and Figure 9 shows the multimedia courseware made by the professional athlete game screenshot (picture from the network, <http://pic.sogou.com/>). Through multimedia teaching [3], students can more intuitively feel the action essentials of the long jump and it is easy to analyze the details of long jump sports, which is impossible to achieve in traditional long jump teaching.

**1.8. Application Analysis of Multimedia Teaching in Long Jump Teaching.** The Chinese health sports curriculum model is aimed at the social reality of the continuous decline in students' physical and mental health. Based on the concept of "Curriculum Standards," it combines the advanced concepts of foreign physical education curriculum models with the practice of China's physical education curriculum reform. The model mainly includes four aspects: purpose and philosophy, theoretical basis, structure and connotation, and solution. It puts forward clear requirements for the teaching behavior of physical education in the physical education classroom, and the specific performance is as follows.

The statistical data of Table 2 and Figure 10 actively advocate the learning method of "independence, cooperation, and inquiry", guide students in doing middle school, doing Chinese thinking, and doing Chinese music, and create a classroom teaching atmosphere with harmonious interaction between teachers and students and a positive atmosphere. Pay attention to the functions of evaluation, such as motivation, feedback, guidance, and development; it requires not only the teacher's evaluation of the students but also mutual evaluation between students [40]. For systematic principles, the selected indicators should serve the purpose of physical education classroom teaching evaluation, based on the essential connotation of physical education classroom teaching

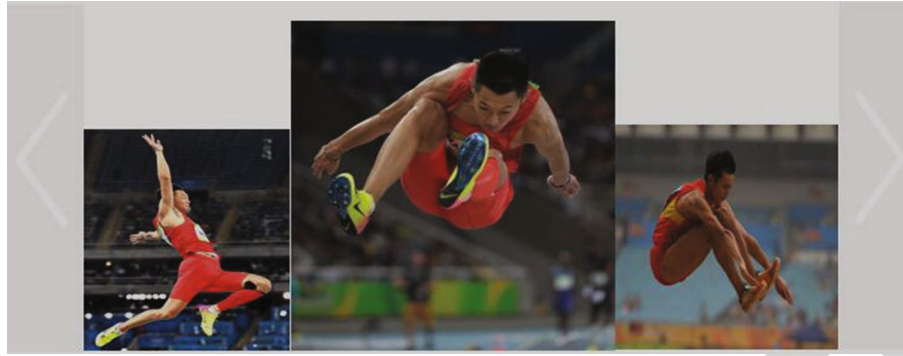


FIGURE 9: Professional athlete long jump technical picture teaching.

TABLE 2: Long jump technical evaluation results in comparison results  $n = 60$ .

Score type	Group	Number	Average score	$T$	$P$
Preexperiment evaluation	Experience group	25	65.1		
	Control group	25	65.4		
Post-experiment evaluation	Experience group	25	88.3	-3.23	$P < 0.05$
	Control group	25	70.1		

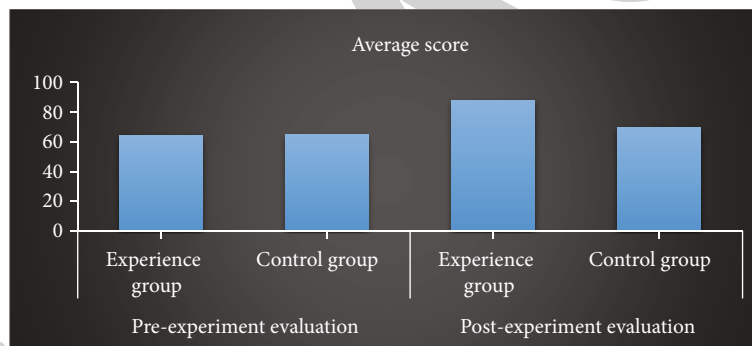


FIGURE 10: Comparative analysis of the results before and after the experiment.

behavior, and can comprehensively and scientifically reflect all aspects of physical education classroom teaching behavior. In the principle of independence, the selected indicators should be independent and irrelevant and cannot be mutually interpreted to ensure the scientificity of the evaluation results.

*1.8.1. Results of the Comparison of Students' Interests in Long Jump.* It can be seen from the figure that for the operability principle, the selected indicators should be simple and clear, be highlighting the key points, and be observable and feasible. The selected indicators need to scientifically reflect the structure and connotation of the Chinese health sports curriculum model, to achieve the cultivation of the core literacy of the subject. At the same time, combined with their theoretical knowledge, it helps the integration of action and theory and makes the long jump technical action change. The control group's rote mode is undoubtedly relatively more action defects, and the long jump technical evaluation results are relatively low. The reason is that the students in the control group use traditional classroom teaching methods, and the students lack motivation in learning, and they do not

understand and grasp the knowledge and skills of the long jump. On the contrary, the students in the experimental group have greatly increased their interest in learning because of multimedia teaching. And the intuitive experience brought by multimedia makes it easier for them to learn and understand knowledge [41].

In order to improve the validity of the experiment and ensure that there is no difference in physical fitness of the students in the experimental class and the control class before the experiment, two sets of related control experiments were carried out, recorded the physical functions, physique, technical indicators, etc. of the experimental group and the control group, and counted the height and weight of the two groups of students. The entire test item is to ensure that there is no difference between the tested individuals and the groups are comparable. The individuals undergoing the experiment were in good physical condition and had no history of the disease, and the test results were subjected to an independent sample  $t$ -test. Table 3 shows the test table between the first experimental group and the control group.

TABLE 3: Physical fitness test table of experimental group 1 and control group 1.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Height	Experimental group 1	$172.52 \pm 6.15$	20	0.23	0.69
	Control group 1	$175.34 \pm 3.94$	20	0.23	0.69
Weight	Experimental group 1	$68.98 \pm 6.25$	20	0.51	0.59
	Control group 1	$69.51 \pm 6.54$	20	0.51	0.59
100 meters	Experimental group 1	$13.54 \pm 0.54$	20	-2.16	0.20
	Control group 1	$12.45 \pm 1.05$	20	-2.16	0.20
Squat	Experimental group 1	$80.34 \pm 16.25$	20	-1.23	0.25
	Control group 1	$85.26 \pm 15.98$	20	-1.23	0.25

TABLE 4: Physical fitness test table of experimental group 2 and control group 2.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Height	Experimental group 2	$175.41 \pm 6.23$	20	-1.55	0.31
	Control group 2	$176.56 \pm 4.58$	19	-1.55	0.31
Weight	Experimental group 2	$70.35 \pm 10.53$	20	0.40	0.90
	Control group 2	$72.28 \pm 7.91$	19	0.40	0.90
100 meters	Experimental group 2	$13.03 \pm 0.52$	20	-1.03	0.61
	Control group 2	$12.83 \pm 0.75$	19	-1.03	0.61
Squat	Experimental group 2	$95.84 \pm 21.36$	20	1052	0.25
	Control group 2	$89.58 \pm 25.08$	19	1.52	0.25

Table 4 shows the test between the second group of the experimental group and the control group. The physical fitness indicators such as height, weight, 100 meters, and squat were subjected to an independent sample  $t$ -test, and the  $P$  values of each result were all greater than 0.05, indicating that there is no significant difference in physical fitness between the experimental group and the control group. Therefore, there is comparability between the groups.

In order to ensure that there is no difference in the technical level of the experimental group and the control group before the experiment, the experimental group and the control group were subjected to the technical evaluation of the long jump technique and the measurement of the achievement of the standard, respectively. At the same time as the technical evaluation, the standard achievement measurement is carried out and the independent sample  $t$ -test is carried out on the statistical results. Table 5 shows the technical evaluation compliance test table of the first experimental group and the control group.

Table 6 is the technical evaluation test table of the second group of the experimental group and control group. It can be seen that before the experiment, the  $P$  values obtained by the experimental group and the control group in the long jump technique and the  $t$ -test of the standard achievement are all greater than 0.05, there is no significant difference in the results, and there is comparability between the groups.

Through the statistics between the two experimental groups and the control group, we can see that the two groups of people have made statistics on the degree of interest in the long jump and the understanding of the rules of the competition. Most of the people are not very interested in the long jump. I do not know the detailed long jump competition rules. Through the statistical analysis of the survey results, in order to further ensure that the experimental group and the control group have no difference in the level of learning interest, the learning interest of the experimental class and the control class is independent. Figure 11 shows the details of these two questions in the first experimental group and the control group.

Table 7 shows that the  $P$  values obtained by the testers of the first group of the experimental group and the control group on the long jump rule survey of the long jump exercise rule survey are all greater than 0.05. There is no significant difference in the specific understanding of the long jump competition rules between the two groups.

The same test experiment was carried out on the second group of the experimental group and the control group, and it was found that the experimental results were different from the first group of experiments. The results are shown in Figure 12. The rules also have a certain degree of familiarity to further ensure that the experimental group and the control group have no difference in the level of interest in the long jump. Similarly, the independent sample  $t$ -test is performed on the investigation results of the experimental class and the control class.

Table 8 is the second group of the experimental group and the control group to test the personnel to understand their understanding of the rules of long jump and whether they know the place of foul; the  $t$ -test was used to investigate the understanding of the long jump rules of the experimental group and the control group. As a result, the  $P$  values obtained were all greater than 0.05, there was no significant difference in the level of learning interest of the two classes of students, and the groups were comparable.

In the second experiment, the same evaluation criteria were used for two different teams. The two groups of people's knowledge of related techniques and foul points in the long jump competition were counted. It was found that the first group of people did not know much about it. The degree of understanding is not great. In order to further ensure that the experimental group and the control group have no difference in their understanding of long jump techniques and rules, an independent sample  $t$ -test was performed on the experimental group and the control group's knowledge of the long jump-related techniques. The specific research results are shown in Figure 13.

It can be seen in Table 9 that the detailed data between the experimental group and the control group in the first

TABLE 5: Experimental group 1 and control group 1 technical evaluation score test table.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Technical evaluation results	Experimental group 1	$34.05 \pm 6.95$	20	-1.84	0.13
	Control group 1	$38.52 \pm 4.94$	20	-1.84	0.13
Achievement	Experimental group 1	$3.98 \pm 0.62$	20	0.52	0.72
	Control group 1	$4.19 \pm 0.59$	20	0.52	0.72

TABLE 6: Technical evaluation score test table of experimental group 2 and control group 2.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Technical evaluation results	Experimental group 2	$39.25 \pm 7.63$	19	0.45	0.58
	Control group 2	$38.29 \pm 11.03$	20	0.45	0.58
Achievement	Experimental group 2	$4.15 \pm 0.52$	19	0.21	0.90
	Control group 2	$5.02 \pm 0.39$	20	0.21	0.90

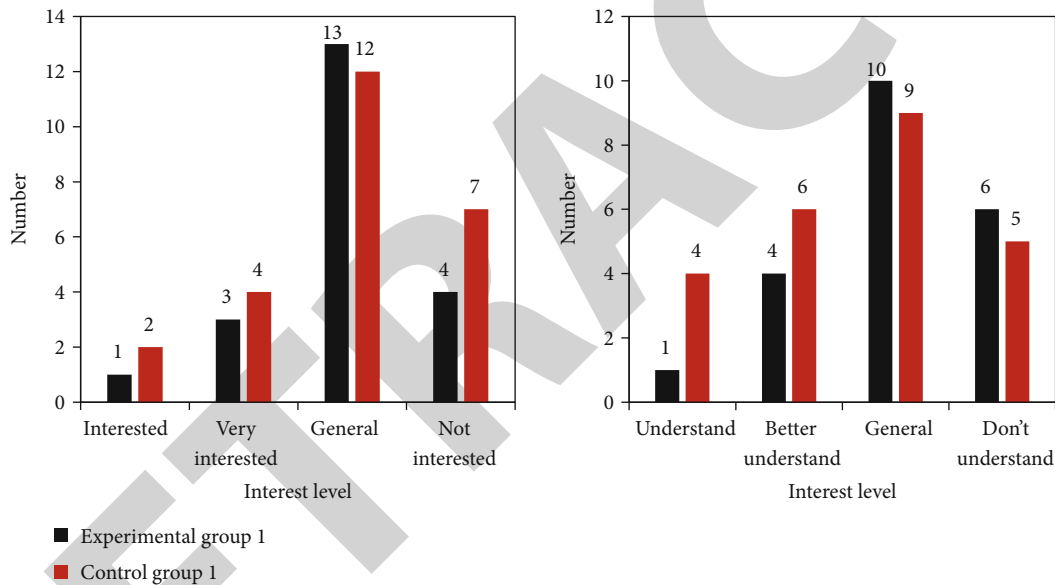


FIGURE 11: Analysis of the familiarity of long jump between experimental group 1 and control group 1.

TABLE 7: Analysis of the degree of understanding of experimental group 1 and control group 1.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Are you interested in long jump	Experimental group 1	$3.16 \pm 0.75$	20	0.36	0.75
	Control group 1	$3.09 \pm 0.83$	20	0.36	0.75
Do you understand the rules of the long jump competition	Experimental group 1	$2.95 \pm 0.62$	20	-0.49	0.71
	Control group 1	$2.72 \pm 0.59$	20	-0.49	0.71

group is shown. In the table, it can be clearly seen that the specific data between the two groups of people on different issues is related to the experimental group and the control group. The  $P$  values obtained by the  $t$ -test results of the personnel's knowledge of long jump are all greater than 0.05. There is no significant difference between the two classes of students' knowledge of long jump, and the groups are comparable.

Compared with the first group of experimenters, the relevant personnel of the second group of experiments have a better understanding of the detailed process and specific rules of the long jump competition and have a better understanding of the common mistakes and fouls in the long jump and master certain corrective methods. To further ensure that there is no difference in the knowledge of long jump between the experimental group and the control group, the

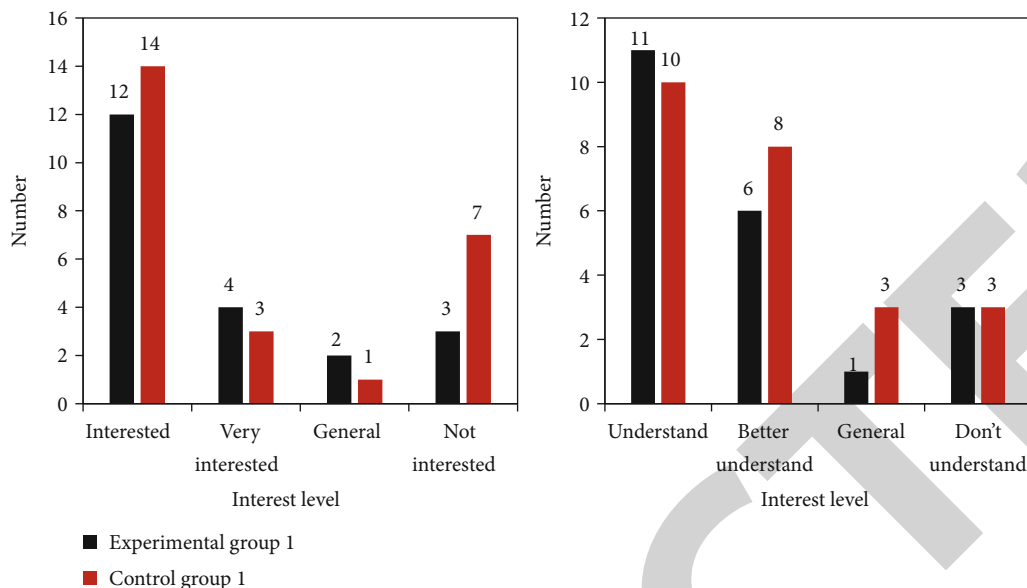


FIGURE 12: Analysis of the familiarity of long jump between experimental group 2 and control group 2.

TABLE 8: Analysis of the degree of understanding of experimental group 1 and control group 1.

Test content	Group	$\bar{x} \pm SD$	<i>n</i>	<i>t</i>	<i>P</i>
Are you interested in long jump?	Experimental group 2	3.08 ± 0.82	20	0.85	0.38
	Control group 2	2.96 ± 0.76	19	0.85	0.38
Do you understand the rules of the long jump competition?	Experimental group 2	3.21 ± 0.69	20	0.22	0.79
	Control group 2	3.12 ± 0.72	19	0.22	0.79

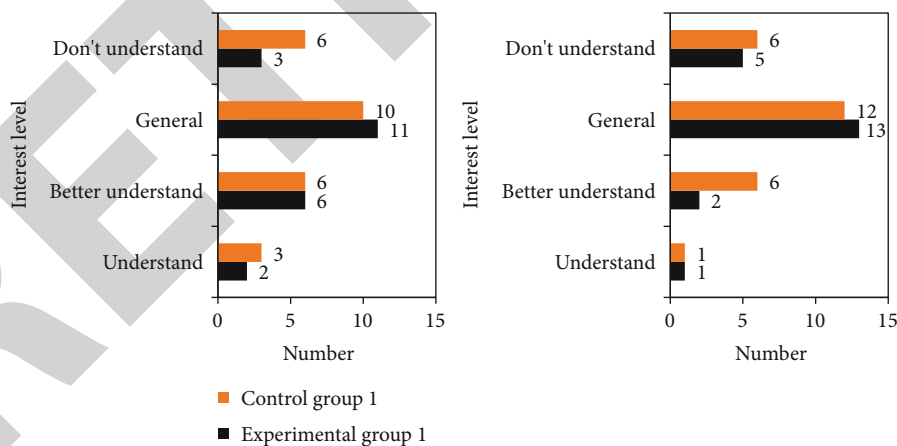


FIGURE 13: Long jump technique understanding analysis of experimental group 1 and control group 1.

independent sample *t*-test was performed on the survey results of the two experimental groups. The specific situation of the second set of experiments is shown in Figure 14.

Table 10 shows the specific situation of the relevant personnel between the second group of the experimental group and the control group. Compared with the first group of personnel, the second group of experimental personnel has better understanding of the long jump project and the *P* value

obtained by the *t*-test results of the relevant personnel of the experimental group and the control group on the knowledge of long jump is greater than 0.05. The relevant personnel of the experimental group and the control group have no significant difference in the level of knowledge of the long jump, and they are comparable between the groups.

In view of the specific analysis of the foul in the actual long jump competition, after each round of long jump

TABLE 9: Long jump rules familiarity table for experimental group 1 and control group 1.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Understanding the long jump technique	Experimental group 1	$2.88 \pm 0.91$	20	0.42	0.65
	Control group 1	$2.92 \pm 0.72$	20	0.42	0.65
Please understand the situation of long jump fouls	Experimental group 1	$1.61 \pm 0.70$	20	-0.85	0.43
	Control group 1	$1.72 \pm 0.59$	20	-0.85	0.43
Understand the situation of the long jump competition process	Experimental group 1	$1.52 \pm 0.73$	20	-0.52	0.55
	Control group 1	$1.63 \pm 0.52$	20	-0.52	0.55

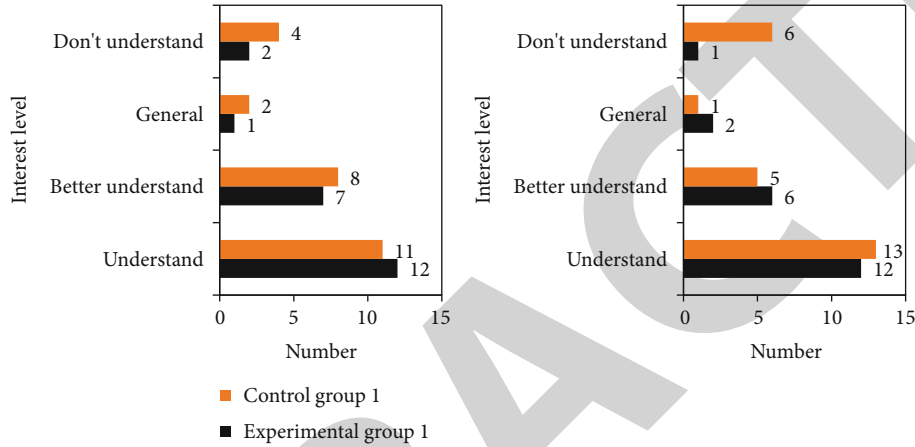


FIGURE 14: Long jump technique understanding analysis of experimental group 2 and control group 2.

TABLE 10: Long jump rules familiarity table for experimental group 2 and control group 2.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Understanding the long jump technique	Experimental group 2	$3.02 \pm 0.76$	21	-0.29	0.78
	Control group 2	$2.97 \pm 0.68$	21	-0.29	0.78
Please understand the situation of long jump fouls	Experimental group 2	$1.31 \pm 0.64$	21	-1.19	0.32
	Control group 2	$1.71 \pm 0.65$	21	-1.19	0.32
Understand the situation of the long jump competition process	Experimental group 2	$1.34 \pm 0.63$	21	-0.68	0.64
	Control group 2	$1.52 \pm 0.55$	2	-0.68	0.64

TABLE 11: Comparison of specific test scores between the two experimental groups.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Technical evaluation results	Experimental group 1	$76.08 \pm 4.46$	20	0.13	0.02
	Control group 1	$67.49 \pm 5.25$	20	0.13	0.02
	Experimental group 2	$65.12 \pm 6.19$	20	-4.18	0.04
	Control group 2	$70.91 \pm 5.06$	20	-4.18	0.04

technical experiment, the long jump posture of each tester was recorded separately and the foul during the long jump was recorded and fed back, as shown in Table 11. According to the actual record, after the end of the specific experiment, the  $P$  value obtained by the  $t$ -test results of the test scores of the relevant personnel of the experimental group and the control group was all less than 0.01 and the experimental

technical evaluation scores of the experimental group and the control group showed significant differences.

After the end of the first round of experiments, the technical actions of the relevant personnel in the experimental group and the control group were studied and analyzed. Table 12 clearly shows that the  $t$ -test results of the relevant personnel in the experimental group and the control group

TABLE 12: Summary table of the achievement test of the two groups of experiments.

Test content	Group	$\bar{x} \pm SD$	$n$	$t$	$P$
Technical evaluation results	Experimental group 1	4.98 ± 0.12	20	1.23	0.26
	Control group 1	5.05 ± 0.31	20	1.23	0.26
	Experimental group 2	5.12 ± 0.25	20	-1.36	0.39
	Control group 2	5.23 ± 0.30	20	-1.36	0.39

TABLE 13: The compliance rate of relevant personnel in the two groups of experiments.

Compliance rate	Total number of people	Number of people meeting the standard	Compliance rate (%)
Experimental group 1	21	21	100%
Control group 1	25	20	80%
Experimental group 2	21	20	95.2%
Control group 2	25	19	76%

TABLE 14: Test results of the first set of tests.

Group number	Actual number of fouls	Detector		Saiban-in	
		Foul	Error	Foul	Error
1	15	15	0	15	0
2	22	22	0	22	0
3	18	18	0	18	0
4	35	35	0	18	20
5	26	26	0	23	11.53

TABLE 15: Test results of the second set of tests.

Group number	Actual number of fouls	Detector		Saiban-in	
		Foul	Error	Foul	Error
6	20	20	0	20	0
7	32	32	0	28	12.5
8	30	30	6.67	13	23.33
9	19	19	0	19	0
10	25	25	0	25	0

have  $P$  values greater than 0.05, reaching the standard. There is no significant difference between the results of the  $t$ -test comparison.

After passing the above experiment, the achievement rate of the relevant personnel of the experimental group and the control group is quite different. Among them, the first group of experimental group and the control group have a higher rate of achievement than the second group of experimental group and control group. This is to a certain extent. This shows that the experimenter who knows the rules has a higher compliance rate, so it can be known that the experiment is a model that has a very important and positive effect on finding the long jump rules. Table 13 shows the specific data summary of the two sets of experiments.

A visual sensor-based long jump stepping and skipping line foul detector is connected to the pulse host through the opposite beam, and a low-voltage pulse is formed at the reflection end and the receiving end of the pulse host to generate a closed circuit. If the athlete takes off and fouls

the rules, the pulse signal will be cut off and the power supply will be disconnected. In this case, the indicator lights and alarms connected to the circuit transmit warning signals, which provide a basis for the referee to determine whether the athlete's long jump stepping fouls the line. The specific results are shown in Table 14.

Table 15 shows the results of the second set of experiments. When judged by the detector, only one set of data has an error of 6.67 but it meets the requirement of the National Athletics Federation Competition Rules that the error of the detection tool is less than 10; when judged by the referee, there are 4 sets of data with varying degrees of error and the errors are all greater than 10. Therefore, the sensor-based long jump line foul detector can accurately detect the number of fouls and the detection accuracy is high, which has certain application value.

## 2. Conclusions

This article combines vision sensor technology with sports events and designs a long jump line foul detector based on vision sensors, which allows athletes to see various long jump techniques and postures well and analyze the existence of athletes in long jumps. For the foul behavior and the correction situation afterwards, the detector consists of a transmitter, a receiver, and a built-in voltage regulator. And the visual warning sound according to the signal provided by the receiver can be used to indicate whether the athlete crosses the line during the long jump. Experimental results show that, compared with the results of traditional manual referees, the long-sensor crossdetector can accurately detect the number of fouls and the crisis errors are lower than the track requirements, which can be very effective in long jump competitions.

## Data Availability

This article does not cover data research. No data were used to support this study.



## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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