Research on Track and Field Teaching and Training Based on Computer-Aided Analysis

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Abstract. At present, the primary method of sports biomechanics research in track and field events is to use a high-speed image analysis system to monitor the training process and obtain kinematics information through special or general analytical software. To improve the training efficiency and correct the defects of technical movements in time, coaches urgently need a kind of equipment that can feedback the movement information in time during the training. Because of this situation, a track and field training information acquisition and feedback system based on a digital track are proposed based on sufficient condensing project requirements. The system USES flexible array sensors obtain contact interaction information during the run-up, and USES special analytical software to process kinematic parameters in an integrated manner, providing real-time biomechanical parameters such as step length and speed step frequency, and takeoff force in the process of moving. The system realizes the comprehensive analysis of sports representation and internal mechanical factors, which helps coaches and athletes to deeply grasp the internal law of the project. Its effectiveness and scientificity have been preliminarily verified through the athletes' testing in the national track and field team's long jump event.

Keywords: Digital runway, Track and field. Biomechanics of sports, Information collection, Computer-aided.

1. Introduction
The development history of competitive sports is a history of continuous development of science and technology. The relationship between sports and science and technology is inseparable, and the vitality of sports depends on the depth and breadth of scientific sports practice to a great extent. Modern science and technology have been comprehensively applied in sports competitive events, especially the comprehensive training instrument based on real-time man-machine interaction and the individual characteristics such as the auxiliary training guidance system based on historical training data, which are more favored by coaches and athletes. Is the essential technical features of this type of training system: according to the characteristics of the design project, comprehensive training equipment (with multiple degrees of freedom of movement, a real-time control, and rapid response-ability), a variety of types of training instrument design, such as the mechanical quantity, photoelectric heat sensors during the training, the various data, through the use of advanced information processing technology to extract valuable information about natural physiology, development based on expert knowledge
(coach) real-time online evaluation system for quantitative evaluation of training effect and history based on individual athletes training data and online programming training guidance system. Not only can be used for the individual ability of intensive training athletes, can according to individual differences athletes, more targeted, strong technique development training effect of feedback analysis at the same time, but the past also relies on the eyes, guidance mode based on feeling experience to see the data, by the analysis of the scientific guidance mode, for coaches field accurately evaluating the athletes' training effect, and provide a scientific basis for the reasonable training plan. Simultaneously, it can also accumulate a large number of excellent athletes' data and build an expert system to help coaches make more scientific and reasonable training plans for athletes' training and significantly improve training efficiency [1].

This study aims to complete the research and development of flexible array sensors' key technologies, master the preparation process and composite pressing molding process, and complete the development of a training guidance system for race walking, middle-distance running, and other projects. The digital runway is mainly used for athlete's daily training and skill evaluation, real-time detection, obtain athletes running, every step of the shape of the sole contact with the runway, time, stride length, step length, and sequence information, can be obtained in lower limbs athletes parameters such as velocity, acceleration, correct judgment for the technical conditions of movement, improve training means and methods, and monitor the training process to provide a scientific basis.

2. The overall design of the system

The system is used in the national track and field team's daily training and evaluates and evaluates athletes' technical and tactical ability, assisting training guidance and comprehensive statistical analysis. Information acquisition: mainly includes kinematics and dynamics information acquisition. The digital track developed based on a flexible array sensor can detect and obtain the shape, time, ground force, and supporting force of the athlete's foot contact with the track during track and field training in real-time to obtain the athlete's step length, stride frequency, and movement time sequence. Data analysis: According to the collected data, the position, velocity, acceleration, and force of the athlete at any time can be accurately obtained. Build a software platform, analyze information, and realize modular training control. The test and analysis software completes kinematics and dynamics analysis, as well as information display and storage. It performs calculation and analysis functions such as conventional file processing, contact image description, histogram pressure map, proportional map, time-series gait parameters, total pressure center track, partial pressure center track, and fundamental power spectrum analysis. By analyzing and discovering the athletes' movement defects, the author gives the reference evaluation and describes the training effect and the athletes' unique technical ability qualitatively and quantitatively. Training guidance: Single movement analysis, comprehensive evaluation analysis, and tracking evaluation analysis can be carried out for a single athlete; comprehensive statistics and comparative analysis can be carried out for multiple athletes; athletes can be grouped and analyzed and compared as a unit; Finally, the expert system is built [2].

2.1. System requirements

The track and field training information collection and feedback system based on digital track are studied to obtain and analyze the obtained motion parameters, including kinematics and dynamics parameters, to realize timely feedback through the feedback system to improve athletes' training level.

2.2. Overall scheme design

2.2.1. Installation structure design. Figure 1 shows the installation structure of the runway. The asphalt foundation is laid under the plastic runway, digital sensors are placed between the runway surface and the asphalt foundation, and the left and right channel steel structures are reserved to facilitate the laying of cables.
2.2.2. System architecture. The system is composed of the upper plastic layer, sensor unit, row lead, train lead, lower plastic layer, sensor acquisition node, field bus unit, digital runway module, field bus, computer, and wireless headset. Its features are as follows: Based on the flexible structure of the sensor array of the screen printing process, multiple sensor units on the protective plastic layer and plastic layer, and between the sensor unit by row and column lead wire connection, sensor acquisition node, multiple sensors to collect node and the plastic layer and plastic layer, Fieldbus unit connection as a training platform for large flexible digital module fixed on the ground, the runway in large-area flexible digital track module, every line of the sensor unit and lead - N sensor unit column connected to the Fieldbus unit, lead through field bus connected to the computer. The wireless headset receives the feedback information from the computer through the wireless communication network. The structure diagram of the system is shown in Figure 2, and the block diagram of system modules is shown in Figure 3.

![Fig. 1 Schematic diagram of runway installation](image1)

![Fig. 2 Schematic diagram](image2)
The system mainly consists of four components: flexible array sensor subsystem, signal acquisition subsystem, wireless real-time feedback subsystem, test, and analysis system software. The flexible array sensor unit and signal acquisition unit can be collectively called the digital runway module. Main functions of each subsystem:

a. The flexible array sensor subsystem

The information acquisition subsystem can measure the real-time movement information of athletes on the digital track.

b. Signal acquisition subsystem

The flexible array sensor’s collected signals are transmitted to the monitoring computer via CAN bus and USB.

c. Wireless real-time feedback subsystem

Can send athletes to the pace of the rhythm to the real-time wireless headset worn by the athletes, and to send real-time instruction of the coaches to athletes, through the real-time feedback unit, real-time athletes can understand the movement in the process of fast rhythm, to adjust the pace at the back of the process, the feedback unit not only can be used for real-time feedback, but can also be used in offline feedback, the athletes can run and jump with the best record repeatedly listen to a rhythm, solidify their own rhythm, can also be a good run and jump and jump with poor do comparative analysis on the rhythm, but the question of This real-time feedback unit also replaces the training method of using a tape recorder to record the running and jumping rhythm [3].

d. Test and analysis system software

By data processing and data mining, the signal collected by the signal acquisition unit is processed and calculated, and the real-time speed, step length, stride frequency, flight time, landing time, takeoff Angle, and other technical parameters of the athlete are obtained. The system software also has athlete file management, data storage, data playback (playback of sports live on the digital track), data analysis, data report (each can generate a single training and a single athlete daily training data report).

2.3. The flexible array sensor subsystem

The preparation of large-area flexible force-sensitive array sensor is the difficulty and foundation of the research, and the key technologies such as the composition ratio of low-temperature force-sensitive
resistor paste, resistance printing method based on screen printing, low-temperature (curing temperature ≤150℃) curing characteristics, and large-area resistance grid uniform preparation process should be studied. The sensor consists of two weak polyester layers, one with rows of ribbon conductors on the inner surface and ribbon conductors' inner surface. The width of the conductor itself and the line spacing can be designed according to different measurement needs. The outer surface of the conductor is coated with an extraordinary pressure sensitive semiconductor material. When two thin films are combined, many transverse and longitudinal conductors intersect to form a pressure sensing point array. When the external force is applied to the induction point, the semiconductor's resistance value will change proportionally with the external force, thus reflecting the pressure value of the induction point. That is, when the pressure is zero, the resistance value reaches its maximum value. The greater the pressure is, the smaller the resistance value is, thus reflecting the pressure distribution between the two contact surfaces. FIG. 4 is the composition diagram of the flexible array sensor subsystem, and FIG. 5 is the original flexible array sensor structure based on the screen-printing process created by intelligent. Through the composite molding process of flexible array sensor and plastic material, the standard template of digital track based on large-area sensor array is developed first in the world, and its preliminary performance and potential application value have been fully affirmed by leaders and coaches in athletics, gymnastics, table tennis and other sports events [4].

**Fig. 4** shows the components of the sensor subsystem

![Component Repository](image1)

(a) Atomic component

(b) Composite component

(c) Composition connector

(d) Exogenous connectors

**Fig. 5** The flexible array sensor structure
3. Acquisition and analysis of dynamic information

3.1. Overview of the underlying control system

The underlying control system mainly consists of a sensor acquisition node and a communication module. The control system has the functions of receiving instructions and collecting sensor signals. The communication module has the functions of implementing CAN bus protocol and USB to interact with the computer, monitoring the running status of the control system, and giving prompt in real-time. The control system mainly solves the following problems: (1) kinematics information acquisition of flexible array sensor; (2) dynamic information acquisition of flexible array sensor; (3) communication mode and protocol; (4) System reliability and stability. Because of the above vital problems to be solved, the underlying control system's design tasks will be described from two aspects of hardware design and software design, respectively [5].

3.1.1. Hardware design. Hardware design is mainly about the reasonable selection of microprocessors, sensors, power supply, other related chips, such as extension chips, etc., to design a control circuit with accurate, flexible, and fast response. It mainly includes the following parts: (1) CPU unit: select the appropriate central micro-controller according to the central control system's real-time and functional requirements. (2) Sensor signal acquisition module: This module includes an address extension unit, scanning drive unit, and sensor signal processing unit. Sampling frequency and working mode are determined according to the system's real-time requirements to complete the acquisition of kinematics and dynamics information. (3) This module includes a CAN communication module, a USB communication module, and alarm prompts. According to the CENTRAL microprocessor requirements, a suitable bus driver chip is selected and the working Baud rate, transmission distance, and transmission reliability are determined. (4) Power module: Design the corresponding power module according to the control system circuit's power supply.

3.1.2. Software design. The task of software design is to plan a flow chart, write a program based on hardware design, and finally realize the functions of the underlying control system. The program should have the following functions: (1) the initialization of relevant hardware. (2) Signal acquisition of flexible array sensor: hardware initialization, scan array function, CAN bus initialization, and interrupt service function. (3) CAN bus communication: related register setting, message mailbox setting, and initialization, interrupt service procedure, baud rate setting, realizing CAN protocol to USB protocol conversion. Besides, the program software must have the following characteristics: (1) program readability: Good software programs must be good readability. A readable program facilitates further expansion and shortens the development cycle for subsequent developers. (2) Efficiency of the program: The system's underlying control system is a control system with high real-time requirements. The interrupt service program code that needs to be called must be completed within a control cycle, so the code execution efficiency should be improved as much as possible.

3.2. Hardware design of the central control unit

The hardware design mainly includes a CPU unit, sensor signal acquisition module, communication module, and power supply module. The CPU unit USES C8051F040 MCU as the control core.

3.2.1. CPU module. CPU module mainly includes an oscillator, I/O port, CAN bus, serial port module, JTAG interface unit, and power module. The hardware design of each unit is described in detail below [6].

3.2.2. Oscillator. The C8051F040 MCU has an internal oscillator and an external oscillator drive circuit, which generates the system clock. The clock has defaulted to the system clock after reset, and the clock source can also be switched to an external oscillator at run time through the CLKSL bit in the OSCICN register, which can generate the system clock using crystals, ceramic resonators,
capacitors, RC, or an external clock source. The clock switching function is useful in low-power systems, allowing the MCU to operate from a low frequency (power-saving) external crystal source and periodically switch to a high-speed internal oscillator (up to 25MHz) as needed. Figure 6 shows the external oscillator drive circuit of the central control unit in the system.

3.2.3. JTAG interface circuit design. To write programs to the C8051F040 microcontroller and facilitate online debugging, a serial adapter or a USB adapter is needed. The serial adapter provides the interface between the RS232 serial terminal of PC and the DEBUGGING/programming circuit of C8051F040 in the system. The serial adapter can supply power from the target via its 10-pin] TAG connector or directly from an AC/DC power source, but the serial adapter cannot supply the target. C805IF040 has a JTAG scanning logic circuit compatible with IEEE Standard L 149.1. IEEE Standard 1149.1 is a series of standards for functional verification of motherboards and chips during motherboards processing. The JTAG scanning logic circuit is used to scan the continuity from pin to pin and test the device's operation on and off the chip. Internal scan logic can access all in-chip resources. Therefore, serial scanning pin and simulation pin can be used for on-chip simulation. The schematic diagram of J1.AG interface circuit is shown in Figure 7.

3.2.4. the CAN communication. C805|F040 has a controller LAN (CAN) controller, and CAN protocol is used for serial communication. Silicon Labs CAN controller conforms to Bosch specification 2.0A(essential CAN) and 2.0B(full function CAN), facilitating communication on THE CAN network. The CAN controller contains a CAN core, message RAM (independent of CL5L of RAM), message processing state machine, and control register. Silicon Labs CAN is a protocol controller that does not provide a physical layer driver (a transceiver). Figure 8 shows an example of a typical configuration on the CAN bus.
Silicon Labs CAN have a working bit rate of up to 1 MBPS, and the actual rate may be limited by the physical layer selected to transfer data on the CAN bus. The CAN processor has 32 message objects that CAN be configured to send or receive data. The input data, message objects, and their identity masks are stored in THE CAN message RAM. All protocol processing of data sending and receiving filtering is completed by the CAN controller without CIP.51 intervention. This minimizes the CPU bandwidth for CAN communication. Ci.51 CAN controller is configured with a particular function register to read received data and write sent data.

4. Dynamic information collection of track and field training

4.1. Position measurement

In position measurement, we can consider each point equivalent as a key. When the force ACTS on the collection point, it can be equivalent to the key being pressed. Because there are many collection points in this design, it is equivalent to a matrix keyboard. In a matrix keyboard, each horizontal and vertical line is not directly connected at the intersection but is connected by a key, reducing the I/O consumption. Using a matrix keyboard, 8 signal lines can constitute $4 \times 4 = 16$ keys, which is twice as much as using signal lines directly on the keyboard. The more lines, the more pronounced the difference is. For example, one more line can constitute a 20-key keyboard, while using port lines directly can only create one more key (9 keys). Thus, it is reasonable to use the matrix method to make a keyboard when the number of keys is large. FIG. 9 is a schematic diagram of position measurement using a matrix keyboard.

Fig. 8 The typical configuration of the CAN bus

Fig. 9 Schematic diagram of position measurement
The matrix structure keyboard is more complicated than the direct method, and the recognition is also more complicated. In Figure 9, the column line is connected to the positive power through resistance, and the I/O connected to the row line is taken as the output end, while the I/O connected to the column line is taken as the input. In this way, when the key is not pressed, all the output terminals are high level, which means no key is pressed. The line output is low, and once a key is pressed; the input line is pulled down so that the input line's status can be read to tell whether a key has been pressed [7].

4.2. Data smoothing and filtering processing

Data smoothing filter drop functions are as follows: first, to remove noise from data; second, to reduce the amount of measured data. Data smoothing aims to eliminate measurement noise to obtain an accurate model and better feature extraction effect. In reverse engineering, the simplest noise removal method is man-machine interaction, which is, through graphic display, to identify clearly bad points and delete them in the data sequence. Obviously, this human-computer interaction method is not suitable in the case of a large amount of data, so the filtering algorithm is mostly used to judge by the program. When using the smoothing filtering method, the information provided by the parameters to be obtained should be kept constant. In general, the smoothing problem of type values at infinite nodes is considered. The smoothing method is to superposition the prototype value linearly to the type value after smooth filtering. The traditional filtering methods mainly include the chord height ratio threshold method, mean value filtering method, and median filtering method [8].

We make use of the principle of median filtering to smooth the collected data. From experience, it can be seen that there is an excellent correlation between the adjacent points of a real object. The coordinates of a particular point are generally very close to those of the surrounding points. This is true even in the boundary part, except for isolated points (which can be generally regarded as noise points). In the point set of the same data collection point, if the coordinate value of a data point is much greater than or less than the value of its neighborhood, in other words, it is clear that the correlation between the data point and its neighborhood is minimal, then the data point can be considered to be polluted by noise. The specific implementation is as follows:

In the acquisition data of an acquisition area, if the data value of a point is the maximum or minimum value of the data value of its neighbor, the point is regarded as the noise point; otherwise, it is the signal point. The following formula can be used to give:

\[
Z_q \in \begin{cases} 
N & Z_q = \min[W(Z_q)] OR Z_q = \max[W(Z_q)] \\
S & \min[W(Z_q)] \prec Z_q \prec \max[W(Z_q)] 
\end{cases}
\]

(1)

According to the above judgment criteria, all data collection points in a collection area are classified, and the coordinate value in noise is replaced by the median value of the coordinates of data points in the area. Set \(p_q\) as the output value of data collection point \(Z_q\) after improved median filtering, then the improved median filtering can be expressed as follows:

\[
p_q = \begin{cases} 
Z_q & Z_q \in S \\
\text{mid}[W(Z_q)] & Z_q \in N
\end{cases}
\]

(2)

The data value \(W(Z_q)\) is the data value of the acquisition area, \(N\) is the noise data, and \(S\) is the standard data. \(\min[W(Z_q)], \max[W(Z_q)]\) Represents the maximum and minimum values of all points in the acquisition area, respectively. \(\text{mid}[W(Z_q)]\) Represents the median value of the data within the
acquisition area. In this method, the signal $S$ and noise $N$ are first distinguished between the logarithmic data points, and different processing methods are adopted to avoid the propagation of noise. For the noise data, it can be deleted or replaced by the median value. In this paper, the latter is selected. There is no loss of data points, and the boundary will not be blurred. Make full use of correlation and location information between data points [9].

5. Test feedback
In the system, it is necessary to establish the measurement standard of training and evaluate athletes' training. However, to improve athletes' technical and tactical level, real-time feedback of the parameters obtained by analysis is provided to athletes to guide them to make the timely improvement, which requires the establishment of a convenient and effective real-time feedback method. In track and field events, due to the uncertainty of athletes' positions, it is impossible to use a wired connection for real-time feedback, which must be realized by wireless technology, and the timeliness, stability, and communication distance of feedback information transmission must be guaranteed, achieve instrumental feedback. We use RF2421 to build a feedback system, which can transmit audio signals conveniently and cooperate with wireless earphones. Athletes can receive real-time exercise data, analysis parameters, and coaches' guidance in real-time with little extra weight. The functional block diagram is shown in Figure 10.

![Functional block diagram of the feedback system](image)

**Fig. 10** Functional block diagram of the feedback system

6. Conclusions
Based on digital track and field training information collection and feedback system is mainly used for track and field athlete's daily training and skill evaluation, real-time detection, obtain athletes running, every step of the shape of the sole contact with the runway, time, stride length, step length, and sequence information can be obtained in lower limbs of athletes parameters such as velocity, acceleration, correct judgment for technical conditions of movement, improve training means and methods, monitor the training process, such as to provide a scientific basis, convenient for athletes and coaches to make better training methods, form a complete set of the training plan, improve the technical level of the athletes.
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