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RESEARCH ARTICLE

Digital and Intelligent Image Processing by Artificial Intelligence and Internet of Things Technology in Sports Fitness Detection

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ABSTRACT With the development and application of the Internet of Things, cloud computing, Artificial Intelligence, big data, and other information technologies, sports fitness has ushered in new development opportunities. Intelligent sports detection has emerged as the times require. This paper takes intelligent physical fitness as the research object, explores the application of digital and intelligent image processing in physical fitness, and provides a theoretical reference for popularizing and implementing intelligent physical fitness in life. Firstly, the treadmill is an example to study the current situation of fitness equipment, especially the intelligent digital treadmill, and the future development trend of fitness equipment. Secondly, the upper and lower computer control scheme is proposed. The upper computer control scheme is selected, and the industrial computer is analyzed. The motion model of the main control motor and the calculation model of the heart rate control scheme and calorie consumption are established. Finally, the software and algorithm design of the control system are summarized, and necessary debugging, experiment, and analysis are carried out. The results show that: (1) the treadmill industrial control system can correctly receive the data sent by the Automatic Voltage Regulator (AVR) and express it in the form of images, which completely matches the asynchronous communication data format. (2) The ultrasonic distance detection experiment proves that the distance precision between the operating platform and the human body is extremely high, and its digital intelligent treadmill can meet human perception and corresponding control requirements well. (3) The heart rate pulse of the human body can be collected based on digital technology. The waveform displayed in the image is relatively stable and complete.

INDEX TERMS Internet of Things technology, intelligence, image processing, physical fitness, heart rate control.

I. INTRODUCTION

In recent years, China has been focusing on developing nationwide physical fitness to meet the growing sports needs of the people and maintain their health. However, in the actual implementation process, there are still many problems to be solved. For example, the use of fitness equipment is not convenient, the construction of the fitness environment is not humanized, and the targeted guidance is lacked in the process of physical exercise [1]. However, with the development of modern information technology, Artificial Intelligence (AI), big data, etc., have been widely used in the medical, education, and financial fields. As an integral part of society, sports must also be affected by modern information technology. All kinds of intelligent fitness equipment and sports fields have begun to develop, making sports move toward the intelligent and digital direction.

This paper will take the treadmill in sports equipment as an example to study fitness detection. Firstly, the current situation of fitness equipment, especially intelligent digital treadmills, and the future development trend of fitness equipment are studied. In view of some shortcomings of the traditional

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treadmill, the research content is determined. Secondly, the upper and lower computer control scheme is proposed. The industrial computer is selected to analyze the upper computer control scheme. The motion model of the main control motor and the calculation model of the heart rate control scheme and calorie consumption are established. Thirdly, the software and algorithm design of the control system are summarized, debugged, tested, and analyzed.

Based on the research of fitness equipment, sports innovation, and scientific fitness exploration of digital and intelligent technology on the treadmill, the current physical training mode has been improved, and the technical support for China's sports power has been realized. Information technology, such as AI, promotes the rise of sports fitness equipment products, making the fitness industry a sunrise industry of green manufacturing and a good way to solve the "lack of exercise awareness" of the public.

II. LITERRATURE REVIEW

Rghioui proposed a more popular concept. The Internet of Things (IoT) is a network that relies on radio frequency identification technology and equipment, combines the agreed communication protocol with the Internet, enables intelligent identification and management of item information, and realizes the interconnection of item information [2]. Its focus in the research field is identification technology. Its definition of the IoT was not comprehensive enough under the scientific and technological background at that time. Later, Wang put forward a more official concept: short-range mobile transceivers are embedded in various accessories and daily necessities to achieve a new way of communication between people, people, and things, and things and things. Interaction can be achieved at any time and anywhere [3]. Noura pointed out that although the concept of the IoT has been widely proposed, there is still no accurate and recognized definition of the IoT. The IoT is the product of integrating various technologies, including sensor recognition, network transmission, data mining, pervasive computing, etc., and requires the integration of multiple disciplines. It is closely related to the Internet, mobile communication, sensor, etc. Researchers in different fields have different starting points for thinking about the IoT. No consensus can be reached in the short term. The theoretical system of the IoT has just risen and has not been fully established [4].

The development of the IoT and mobile Internet technology has promoted the research, development, and design of large-scale fitness equipment and is also constantly carrying out technological reform and upgrading [5]. My Wellness, launched by the Italian Technogym Company, realizes the monitoring and management of daily life and professional fitness through micro portable measuring equipment, treadmills, strength trainers, etc. Users' fitness data can be shared on the My Wellness platform and get programmed fitness guidance [6]. The Icon launched by ICON Health & Fitness, Inc. gives full play to the advantages of the application of smart mobile phones such as Apple and realizes the design of a treadmill controlled by mobile phones. Additionally, it cooperated with Google Maps to achieve the reproduction of virtual scenes during fitness [7]. In China, Cheng and other researchers analyzed the safety problems and their causes in using the treadmill and proposed a personalized management system scheme for the ZYZN-1 network intelligent treadmill. Based on the analysis of the exercise state of fitness users and the related intelligent managers, data storage is realized, and the fitness files of users are established using data collection. Then, the application provides users with digital exercise plans and schemes for reference [8].

Yang proposed a new field of computer application research - sports computing, which is a computer application technology that applies computer technology to the sports competition and their management [9]. With the introduction of the body area network standard IEEE 802.15.6, wireless communication within the human body has become possible. In the future, the physical activity measuring instruments (i.e., biosensors) transplanted into the human body will form a wireless network. These sensor nodes will collect important physiological signals of the body (such as temperature, blood sugar, blood pressure, etc.), human activity or action signals, and information about the environment where the human body is located to achieve a comprehensive perception of the human body [10]. From the development and design of a variety of web-based human data monitoring products, the new fitness model led by fitness life will lead a new boom in the development of fitness industry in the future based on the cross integration of computer science, social networks, intelligent devices and the fitness industry [11].

The innovation is to combine the content of IoT technology integration with traditional sports items to form a digital and intelligent sports fitness type. Secondly, the upper and lower machine control system of the treadmill is modularized to ensure the development, readability, and scalability of this technology.

III. MATERIALS AND METHODS

A. OVERVIEW OF THE IoT

As a new generation of network service technology, the IoT also has its unique characteristics, namely perception, interconnection, and intelligence, as shown in Figure 1:

The characteristics of interconnection are reflected in the rapid development of modern networks. The use of wired and wireless networks can extend the perception of things to many corners of human life and provide information transmission channels for the interaction between things based on network coverage. The perceptual feature is to use sensor technology and sensor network technology to make "things" connected to the IoT have their own sensory organs so that they can feel the changes of the external environment and make reasonable responses; The intelligent feature is based on the realization of data perception and transmission, and uses supercomputers and cloud computing systems to mine and calculate the data and feedback the results [12].

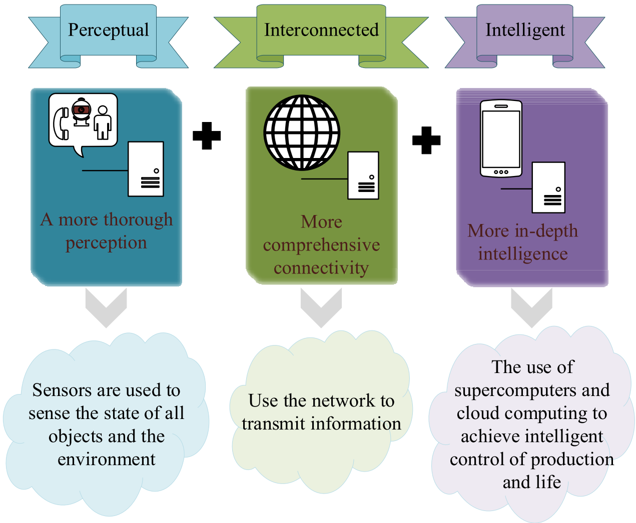

FIGURE 1. Features of the IoT.

The application of IoT technology breaks through space and time constraints and realizes the real-time allocation of data collection, transmission, storage, mining, and other services. The working process of the IoT is like that of human perception and processing of the physical world. Human beings use various senses to obtain information, use neural organizations to transmit the information they feel, and use their brains to process and give feedback on the information [13]. The architecture of the IoT is shown in Figure 2:

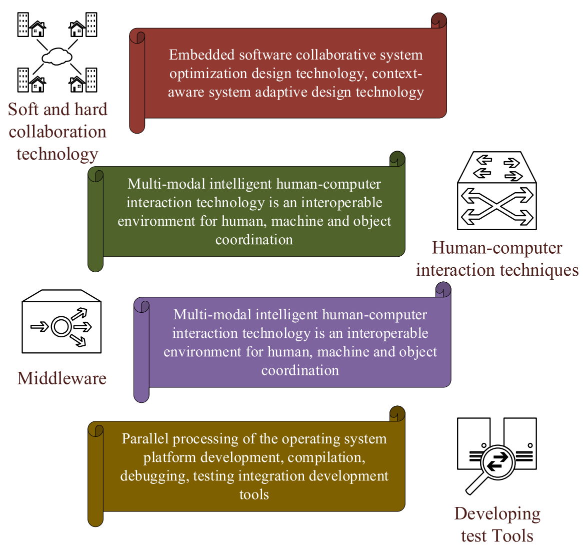

FIGURE 2. Architecture of the IoT.

The network fitness service supply mode based on the fitness equipment of the IoT can be planned as a complex system using the hierarchical structure thinking of the IoT system. The fitness service based on the IoT technology can be divided into four layers: perception, equipment, transmission and service. Between each layer, data information can achieve effective interaction and two-way communication, and the information transmitted is diverse, including static and dynamic information required in fitness services [14].

B. OVERVIEW OF DIGITAL SPORTS

Digital technology is a technology that uses discrete and discontinuous values to represent signals. In computer recognizable language, information is composed of 0 and 1. Digital technology is to use computer recognizable language to transform pictures, videos, texts, and other information to realize the storage, utilization, and presentation of information [15]. The networked sports work detection system is shown in Figure 3:

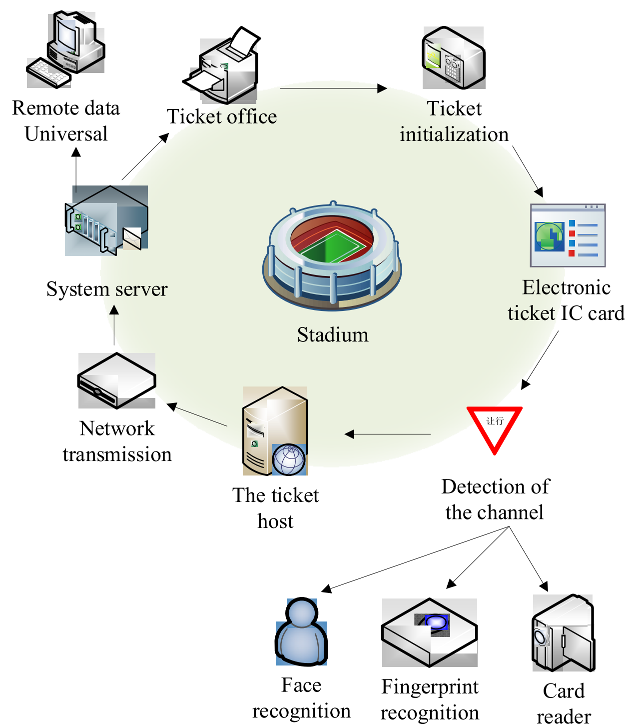

FIGURE 3. The detection system of network sports work.

The combination of sports and digital technology has a unique internal link. Digital technology has become an important measure in this field to guide competitive sports training. Computer simulation technology is one of the most popular application technologies. The basic idea of simulation is to use physical or mathematical models to simulate the real process to seek an understanding of the real process [16].

C. THE PROCESSING TECHNOLOGY OF COMPUTER IMAGE

Computer-aided design is the earliest and most important application field of computer graphics, the most extensive and active field in the industry. The use of technology not only improves the design efficiency but also shortens the design cycle, improves the design quality, and reduces the design cost. Still, it also can establish a database for the computer-aided manufacturing of the subsequent processes and make it integrated, laying the foundation for production automation [17]. Figure 4 shows the flow chart of computer rapid graphic formation.

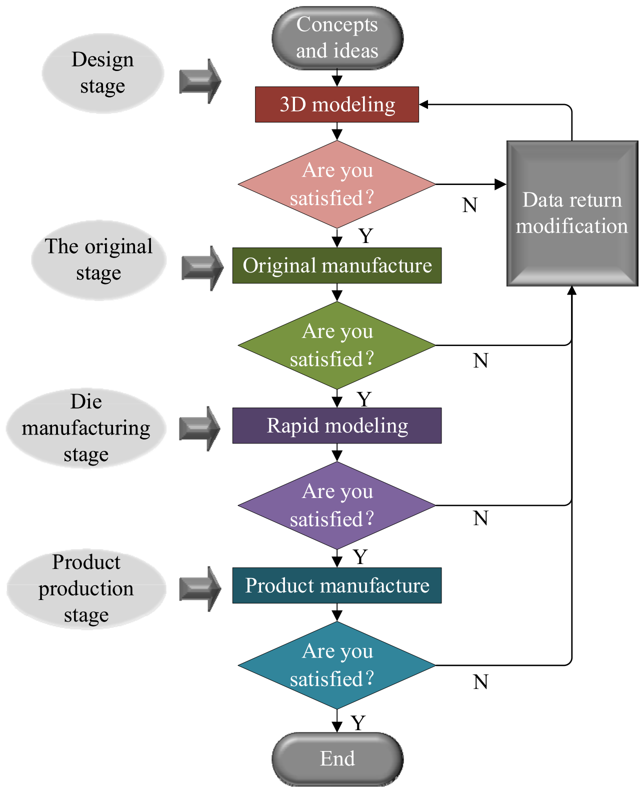

FIGURE 4. **The graphic flow of rapid computer formation.**

With the rapid development of computer graphics technology, its application in animation and its connotation are expanding. The development of computer animation today is mainly divided into two stages, namely computer-aided and computer-generated animations. Computer-aided animation is also called "two-dimensional (2D) animation", and computer-generated animation is also called "three-dimensional (3D) animation". Figure 5 shows the image steps of computer processing "deformation".

In the stage of computer-aided animation, after generating several pictures called "keyframes", the computer interpolates two keyframes to generate several "intermediate frames". When the two keyframes are played continuously, they can combine, greatly improving animation production quality and efficiency [18]. Also, modeling tools create realistic actors and scenes in key frames [19]. There are many methods of computer-aided animation. Feature-based image deformation includes 2D shape blending, axis deformation, 3D free-form deformation, etc.

With the development of image processing technology, computers are also widely used in sports, such as elasticity, depth, and angle detection of a human collision. The standardization of human motion posture can obtain accurate data from computer image monitoring to infer whether the moving

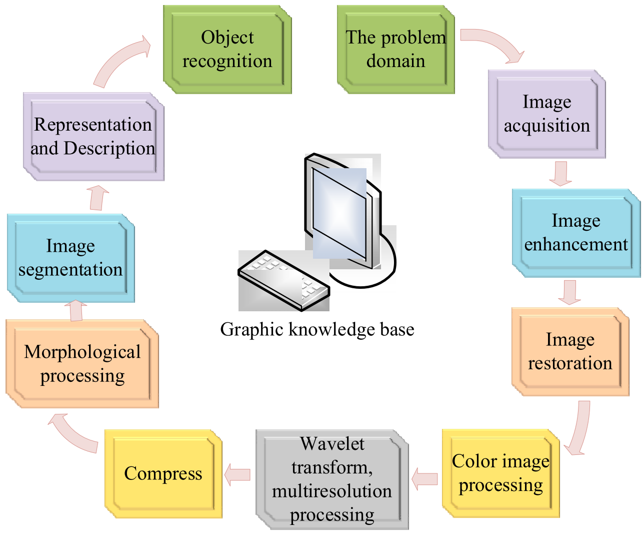

FIGURE 5. **Computer processing image "deformation" steps.**

object or target meets the standard [20]. The mechanical equation can also be used. Suppose that when the foot and the treadmill are stressed, the maximum pressing depth of the shoe is *MaxD*, and F. represents the elastic force generated by the rubber particles per unit area. When the sole is in the state of maximum pressing depth, the number of rubber particles that can be contacted is expressed in *N*. The height and density of colloidal particles are the same. The above can be regarded as constants. The expression method of the elastic potential energy of rubber coating can be obtained, as shown in Eq. (1):

$$G_{rubber} = \pi(\frac{d}{2})^2 NFM\text{axD} \tag{1}$$

In Eq. (1), $\pi(\frac{d}{2})^2$ is the surface area of colloidal particles. The elastic potential energy of the rubber coating is in direct proportion to the square of the rubber particle diameter. If the proportion coefficient is k, then k can be expressed by Eq. (2).

$$k = \frac{1}{4}\pi NFMaxD \tag{2}$$

Therefore, the expression of elastic potential energy can be converted into Eq. (3).

$$G_{rubber} = kd^2 \tag{3}$$

According to the law of conservation of energy, the kinetic energy E of the foot when it leaves the machine is shown in Eq. (4):

$$E = \frac{1}{2}mv^2 \tag{4}$$

Thus, the Eq. (5) can be obtained:

$$\frac{1}{2}mv^2 = kd^2 + G_p \tag{5}$$

In Eq. (5) m is the mass of a person, which can be regarded as a constant, and v is the speed at the moment when the foot leaves the machine. Then, the size of v is shown in Eq. (6):

$$v = \sqrt{\frac{2kd^2 + 2G_p}{m}} \tag{6}$$

Set $\frac{2k}{m}$, $\frac{2G_p}{m}$ is k1 and k2, respectively. The formula can be simplified, as shown in Eq. (6):

$$v = \sqrt{k_1 d^2 + k_2} \tag{7}$$

According to the definition of acceleration ability during running, the relationship between leg acceleration ability and machine rubber particles can be obtained, as shown in Eq. (8):

$$S_a = \frac{\sqrt{k_1 d^2 + k_2}}{v_0} \tag{8}$$

D. HARDWARE SYSTEM OF TREADMILL SYSTEM

The control hardware of the upper computer uses Visual C++6.0 to develop the main tools of the Human-Computer Interaction (HCI) interface. The main functions include: starting and exiting the treadmill, speed control, and slope control. In addition, the Software Development Kit (SDK) function of the video capture card is redeveloped. The input signal is controlled to realize watching, recording, and picture size adjustment of cable and wireless television (TV) programs and other videos [21]. The control hardware structure of the upper computer is shown in Figure 6:

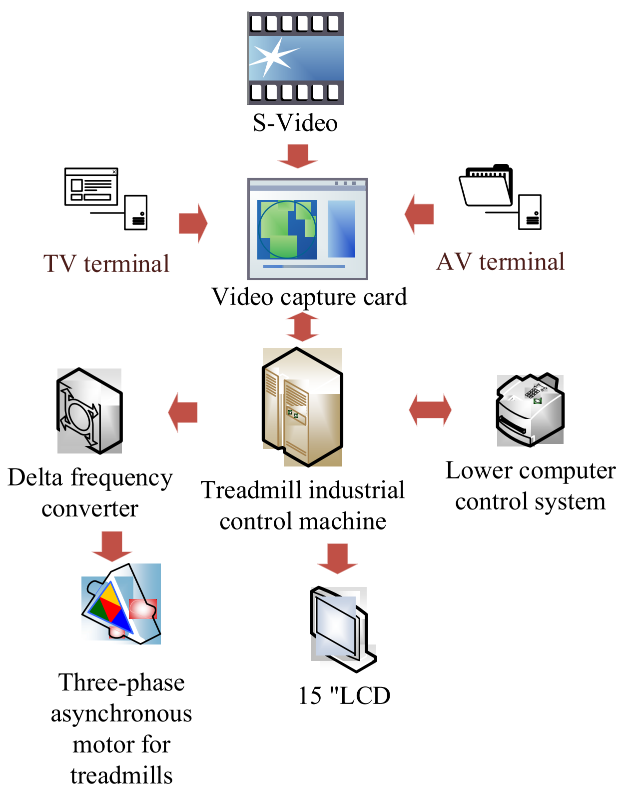

FIGURE 6. The hardware structure of the upper machine position control.

The video capture card in the upper computer uses Impress hard-pressed king video capture card, which provides S-Video and TV input terminals. The integrated TV tuner supports watching and recording cable and wireless TV programs and can adjust the picture size. It is compatible with PCI2.1 and Windows Plug and Play [22].

The lower computer's bottom control system in the AVR microprocessor control system is mainly composed of an embedded microprocessor board, which is mainly responsible for heart rate detection module, emergency safety locking module, function key module, lifting motor control module, etc. [23]. Its hardware system composition is shown in Figure 7:

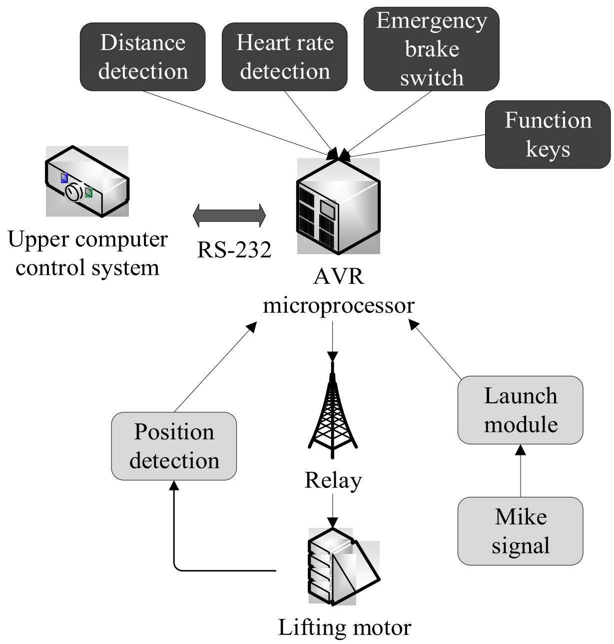

FIGURE 7. Composition of hardware system.

According to the existing heart rate recognition and control methods, some systems can control the heart rate of the project. The heart rate of the experimenter can be measured, for example, with a wristwatch sensor or a chest band detector, which requires the exerciser to prepare in advance [24]. In this subject, users use the hand electrode type heart rate sensor without wearing anything, and the hand electrode detection device can also function for a long time. When detecting ultrasound, the detection of ultrasonic distance is shown in Eq. (9):

$$d = \frac{C * t}{2} \tag{9}$$

The microprocessor sends the control command of transmitting ultrasonic waves and simultaneously turns on the counting. Once the reflected ultrasonic signal is received, the counting will stop, and the ultrasonic transit time t will be obtained. The distance value can be obtained according to the equation, where C represents the propagation speed of the ultrasonic wave in the air.

IV. MODEL DESIGN

A. DESIGN OF HEART RATE CONTROL FOR INSTRUMENT DETECTION

The better the health, the slower the heart rate; within a fixed time, the number of heartbeats is less [25]. Compared with people with 70-75 beats/min, people with 40-50 beats/min have a difference of 36000 beats per day. This makes a considerable difference in the heart's workload [26]. Maintaining good physical fitness requires a consistent exercise program. If people do not exercise for two weeks, their cardiopulmonary function will significantly reduce. Table 1 is the comparison table of exercise heart rate and age.

TABLE 1. The comparison of exercise heart rate and age.

heart rate	20~30 years old	30~40 years old	40~50 years old	50~60 years old	60~70 years old
strong	165	157	148	140	132
weak	141	134	128	121	114
commonly	117	111	106	99	93

In Table 1, people of different ages give three different exercise heart rate levels: strong, medium, and average. Heart rate is different for people of different ages. People around 20 years old have a strong heart rate of 170 beats/minute, a moderate heart rate of 145 beats/minute, and a general heart rate of 120 beats/minute. Figure 8 shows the control flow of an intelligent device for young people's heart rate detection.

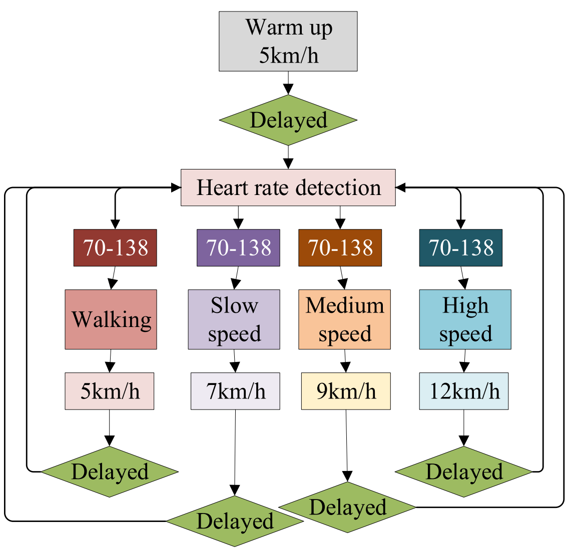

FIGURE 8. Control flow of intelligent devices for young people's heart rate detection.

The machine control system can automatically provide a scientific movement scheme according to the user's heart rate, age, and other conditions and realize intelligent movement guidance. Suppose the user is a girl or a relatively weak group. In that case, the exercise program needs to be adjusted appropriately to adapt to the physical conditions of different genders and age groups.

B. THE DESIGN OF INDUSTRIAL COMPUTER TESTING

The connection circuit of asynchronous serial communication between the upper computer of the system and the AVR lower computer is shown in Figure 9:

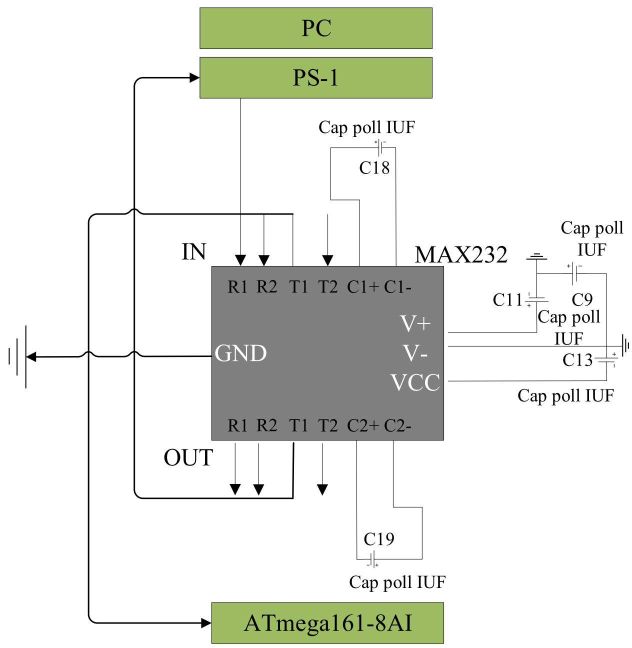

FIGURE 9. Circuit connection diagram of AVR lower stand.

According to the circuit connection in Figure 9, the AVR lower computer microprocessor sends the data to the upper computer industrial control computer based on the USART interface. If the experiment is to detect the received data observed by the upper computer and prove the correctness of the circuit design and connection, as well as the sameness of the communication baud rate and data frame of both sides. Before writing the special interactive interface program, the green "Serial Port Debugging Assistant V2.2" in the IPC system platform was used to detect [27], [28].

Test 1: in order to prove that the circuit of the RS-232 level conversion part of the AVR system is correct. The MAX232 circuit is considered to detect the transceiver of the single-chip microcomputer; that is, the RS-232 interface of the AVR system formed by RS-232C level conversion.

Test 2: connect the RS-232 port of the industrial computer with the RS-232 port of the AVR microcontroller with a RS-232 connection line, and run the serial port debugging assistant V2.2.EXE software on the upper computer. Firstly, open the serial port, and set the COM port, baud rate, check bit, data bit, and stop bit of serial communication as COM1, 9600, NONE 8.1 to ensure that the data frame format and baud rate of the upper computer and the lower computer are consistent. In addition, the data in the test is not displayed in ASCII code, so the hexadecimal display mode should be selected to display directly in hexadecimal data.

V. RESULTS

A. INDUSTRIAL PERSONAL COMPUTER TEST

After all settings are configured, the data sent by the AVR system of the lower computer is displayed in the receiving area of the serial port height assistant, as shown in Table 2:

TABLE 2. AVR system data feedback.

Serial port	Baud rate	Data bits	Stop bit	Check bit
COM1	9600	8	1	NONE
00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09 00 01 02 03 04 05 06 07 08 09				

In Table 2, the hexadecimal numbers from 00 to 09 that test wants to transmit appear in the receive window. The data indicate that the industrial control function correctly receives the data sent by AVR. The underlying physical connection of the lower computer and the asynchronous communication data format adopted by both the upper and lower computers are also correctly matched.

B. DETECTION OF THE ULTRASONIC SAFETY DISTANCE

At the beginning of the experiment, no matter how the ultrasonic probe detects the signal (processed signal), it is a periodic square wave. This is the expected signal. When the resistance value of R27 is changed in the experiment, and the resistance of 220 Ω is selected, a high level is detected when the ultrasonic probe receives the signal. A low level will appear with the movement of the obstacle. The data shows that the signal detected at this time is also the signal expected to change with the movement of the obstacle. Then, when the experiment carries out the specific distance test, the signal cannot be detected when the distance reaches a certain value. The data shows that R27 uses resistance of 220 Ω, resulting in a smaller gain, which makes it impossible to measure at a longer distance. Figure 10 shows some data measured in ultrasonic ranging.

The accuracy of nine groups of different distances between the treadmill operating platform and experimental volunteers measured by ultrasonic is 0.008m, 0.012m, 0.018m, 0.013m, 0.016m, 0.017m, 0.016m, 0.015m, and 0.008m, respectively. Compared with the length of the whole treadmill of about 1.2m, the measurement accuracy meets the human perception and corresponding control requirements of the digital intelligent treadmill.

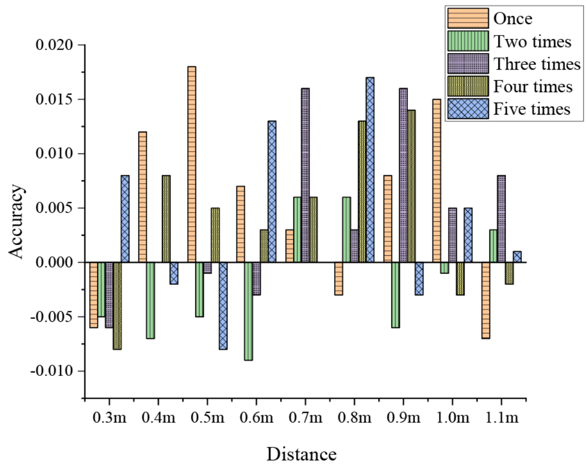

FIGURE 10. Results of ultrasonic ranging display.

C. MEASUREMENT OF HUMAN HEART RATE

In the experiment, healthy volunteers are searched for heart rate detection, and their heart rate pulse maps are collected. The heart rate results are shown in Figure 11:

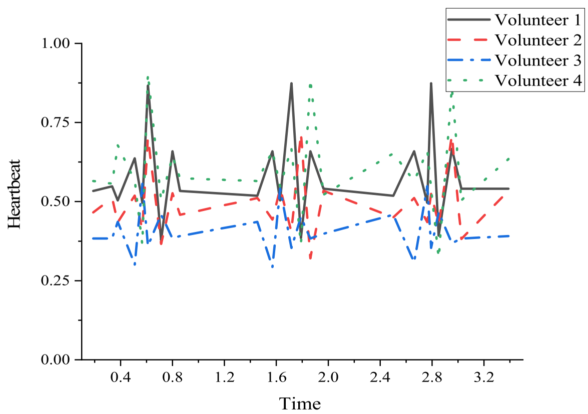

FIGURE 11. Heart rate pulse results of volunteers.

The detected heart rate shows that the measured waveform is relatively stable and complete. The image presentation effect can easily get the heart rate of each member.

VI. CONCLUSION

In modern social life, intelligent devices based on digital and intelligent services are widely used. Product application services based on AI also emphasize the integration of intelligent devices and the IoT. The innovation and development in these fields provide a more mature environment for applying IoT technology. For example, this paper will explore the application of such technology in the field of physical fitness. The current situation of fitness equipment, especially intelligent digital treadmills, and the future development trend of fitness equipment are studied. Some shortcomings of the traditional treadmill are used to determine the research content. The upper and lower computer control scheme is proposed, and the industrial personal computer is selected for analysis. The main control motor's motion model, the heart rate control scheme, and the calorie consumption model are established. Finally, the software and design of the control system are summarized, tested, experimented with, and analyzed. The result shows that the industrial control system of the treadmill can correctly receive the data sent by AVR and express it in the form of images, which completely matches the asynchronous communication data format. Secondly, the ultrasonic distance detection experiment proves that the distance precision between the operating platform and the human body is extremely high. Its digital intelligent treadmill can meet human perception and corresponding control requirements well. The heart rate pulse of the human body collected by digital technology is displayed, and the waveform displayed by the image is relatively stable and complete.

This experiment takes the treadmill as an example to discuss, and the implementation of control for various fitness equipment and fitness methods requires the development of multiple types of integrated control chips. Data communication and image transmission between different control units and intelligent devices also need further improvement.

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