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Article

Monitoring system for physical activity and fitness based on service robots and biomechanics

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Abstract: Exercise is one of the important ways for people to exercise, with characteristics such as sociality and strong participation. Especially with the improvement of the level of economic development and the improvement of the quality of life of the people, more and more people begin to attach importance to the maintenance of their own health. Physical fitness monitoring, as an effective means, is widely used in daily life, especially among the elderly. However, most of the existing monitoring methods are relatively simple, lacking pertinence, and the data collection process is relatively cumbersome and unstable, which cannot meet current needs. Therefore, it is very necessary to explore a new type of equipment that can more comprehensively and accurately monitor various physiological parameters of the human body to replace existing traditional detection technologies. Service Robots are currently the most promising intelligent hardware products. They mainly provide personalized services centered on users, sensing user behavior and implementing intelligent decision-making based on their characteristics, thereby better meeting the needs of different groups of people. This article focused on the research and development of Service Robots, and designed a comprehensive solution for Service Robots based on theories such as the Internet of Things, cloud computing, big data technology, and artificial intelligence. This article compared existing intelligent monitoring systems with fitness monitoring systems based on Service Robots, and proved that the user experience of fitness monitoring with robot participation has improved by about 4.68%. Its application scenarios were richer and its effects were more significant, enabling it to better complete tasks such as analysis and prediction of physical fitness status, real-time warning, etc., reducing the risk of people suffering from diseases, and enhancing individual protection awareness.

Keywords: intelligent health service; intelligent robot; biomechanics; physical fitness monitoring

1. Introduction

The research purpose of this paper is to develop a physical activity and health monitoring system that combines service robotics and biomechanics.The system uses high-precision sensors, data analysis algorithms, and service robot interaction to comprehensively and accurately monitor human movement, and provide feedback, suggestions, and early warnings.The research aims to solve the problems of inaccurate data, incomplete services and insufficient interaction in the existing technology, in order to improve the user experience and the practicality of the system. The research focus is to integrate technologies such as the Internet of Things and cloud computing to create a service robot platform that can identify users' physical fitness and meet individual needs.Specifically, it includes optimizing the sensor layout to improve monitoring accuracy, using biomechanical models to provide customized exercise guidance, and designing intelligent algorithms to achieve health prediction and early warning. The contributions of this research are: To promote the collaborative development of intelligent health monitoring and service robots, and to provide a new paradigm for smart medical care; to propose an evaluation system for the effectiveness of service robots in health promotion to provide the basis for follow-up research; to promote the personalization and intelligence of health management, which is essential to the innovation of health care in an aging society. In short, through technological innovation, this research strives to create a more accurate and personalized health monitoring system to meet existing challenges and lay the foundation for future health management and care models.

1.1. Development history of intelligent health robots

Since mankind entered a civilized society, global technology has developed rapidly, and information technology is changing rapidly. Artificial intelligence, represented by intelligent speech and video recognition, has gradually been applied in people's lives [1,2]. Intelligent robots have also begun to penetrate from the field of industrial automation to applications such as medical care and home services [3,4]. Service Robots are the new direction and development trend of the current smart home industry [5]. Compared with traditional household appliances, it has the characteristics of high intelligence, remote control, and autonomous learning [6]. It provides a convenient, efficient, safe and comfortable intelligent home environment, enabling information sharing and knowledge exchange between people and devices.

1.2. Role of using robots for body fitness monitoring

1.2.1. Being able to respond in a timely manner to any discomfort during human movement

Robots have the ability to perceive and coordinate movements, and in many cases can be used as auxiliary operating devices, making it easier for people to understand their body status and make corresponding adjustments [7]. For example, when a person suddenly falls, the robot would automatically come forward and lift him up, helping the patient quickly recover their physical strength or resume their normal lifestyle. It can also be used by robots to replace medical personnel in performing inspection and treatment of patients, assisting doctors in rapid diagnosis and treatment of diseases, which greatly shortens the recovery time.

1.2.2. Real-time monitoring be achieved to provide basic data support for subsequent work

For robots, after collecting human motion information through sensors, the system would issue instructions based on relevant signals to control the execution of the actuator. Real-time recording of various parameters, such as speed and weight, ultimately achieves the desired purpose, and uploading this information to the cloud for subsequent personnel to analyze and judge the obtained information. This can contribute to better health management and services.

1.2.3. Avoiding human intervention is conducive to improving work efficiency

Robots are intelligent devices whose intelligent level directly affects people's quality of life and safety issues. Using robots as an auxiliary means during sports training can effectively alleviate athlete fatigue and reduce physical consumption [8]. When encountering emergency situations, it can also provide early warning, thereby reducing unnecessary injuries and greatly improving medical efficiency.

2. Development trend of robot based body fitness monitoring system

Physical fitness training is an essential part of the development of human body functions, which is of great significance for improving physical fitness and enhancing athletic ability. With the rapid development of sports and the continuous improvement of people's living standards and health awareness, more and more people begin to pay attention to exercise methods and methods. Advanced technology is needed to analyze and process data during physical fitness testing. As one of the main application systems, robots can effectively help people solve practical problems. Currently, robots have been widely used in fields such as sports competitions and scientific research to measure various physiological indicators of the human body, realizing the advantages of high efficiency, good accuracy, and high degree of automation [9,10]. However, due to external factors, some failures may occur during use. Therefore, to ensure the accuracy and reliability of the entire test results, it is necessary to reasonably optimize them.

The monitoring of physical activity and fitness is a necessary prerequisite for ensuring the normal physiological activity requirements of the human body, promoting growth and development, and preventing diseases. Many scholars have studied it from different perspectives. By focusing on the latest advances and challenges in mobile and wearable devices in assessing and promoting physical activity and fitness, as well as monitoring heart rate and rhythm to detect and manage atrial fibrillation, McConnell, Michael V provided the latest advances in cardiovascular mobile health [11]. Kocielnik, Rafall introduced a mobile conversation system that supported participatory reflection of personal sensing data. Physical activity data collected through fitness trackers helps users improve their athletic abilities and promote health management [12].Lynch, Chris attempted to use fitness trackers to change the physical activity behavior of adults, monitoring and recording people's daily exercise and heart rate changes to understand human health [13].

Singh, Pawan reviewed medical systems based on the Internet of Things and outlined the opportunities and challenges faced by patient health monitoring systems based on the Internet of Things, laying the foundation for further development of medical informatization [14]. Nieman, David has studied the relationship between physical activity and the body's defense system, improving the accuracy of assessing human athletic ability, and reducing the risk of common chronic diseases [15]. Joensuu, Laura evaluated the relationship between body composition, physical activity, and maturity and physical health during adolescence. Through data monitoring of youth groups of different ages, he revealed the role of exercise intervention in improving human health [16]. The monitoring of sports data can not only be used to guide sports coaches in formulating training plans, but also help to analyze the physical fitness of athletes and their related indicators, in order to better meet the growing needs of people for physical exercise.

Using intelligent service robots to monitor physical fitness is one of the important means to improve human work efficiency. Many scholars have proposed some ideas and carried out a series of research work. Wang, Tian-Miao discussed the development trend of intelligent robots and summarized the research on key and cutting-edge technologies such as human-computer collaboration and bionic robots. This can provide relevant theories, methods, and technical guidance for intelligent robot assisted motion monitoring [17]. Khamis, Alaa elaborated on the role robots and automation can play in combating catastrophic pandemics. He emphasized their ethical impact in emergency situations and the post pandemic world, providing theoretical support for the application of robots in areas such as activity monitoring and physical fitness monitoring [18]. Mende, Martin studied the research results of service robots in aspects such as fitness monitoring, motion control, and intelligent perception. By collecting data from sensors, it realizes the positioning of human joints and limb parts and the recognition of movement targets [19].

Wirtz, Jochen explored the important impact of intelligent service robots on all key stakeholders at three levels: personal customer experience, market and social impact of specific services. Taking motion monitoring as an example, he conducted empirical analysis, demonstrating the advantages of intelligent service robots in enhancing user satisfaction and reducing enterprise operating costs [20]. Srinivasa has built an intelligent medical monitoring system based on data analysis, which performs real-time monitoring of various areas within the hospital through intelligent robots and video analysis technology [21]. Through a survey of the theoretical framework of service robots, Belanche, Daniell believed that it had a good correlation with sports health management, and proposed to introduce this concept into intelligent services, using intelligent service robots to meet people’s actual needs [22]. The application of Service Robots has realized real-time interaction between people and the environment, improving people’s quality of life.

In order to solve the problems of unstable sensor data collection process and distortion of perceptual information caused by sensitivity to external environment changes in existing robot fitness monitoring systems, this paper analyzes the characteristics of human motion and posture, and designs a new robot model based on intelligent health services that can be used for fitness monitoring. It realizes real-time state judgment and early warning in different situations, effectively improving detection accuracy. Compared with other types of robots, this model can perform multiple ways of mobile positioning, provide personalized customization services for users, and have automatic obstacle avoidance capabilities, facilitating flexible adjustments based on actual needs. This multifunctional feature makes it more widely used and can well meet the needs of most intelligent devices in the current market [23].

3. Process of intelligent service robot assisted body fitness monitoring

3.1. Motion monitoring algorithm

The intelligent service robot described in this article not only integrates diversified sensor technologies, but also has carried out in-depth expansion and innovation in functions and applications.This robot is equipped with a three-axis accelerometer, which can accurately capture every subtle movement of the body. At the same time, the addition of the gyroscope enables the robot to monitor the user's posture changes in real time, so as to more comprehensively understand the user's movement status. In order to enhance the accuracy of spatial positioning, the robot also incorporates magnetometer technology. The application of heart rate sensors is not only used to evaluate the intensity of exercise, but also to reflect the user's health status in real time, and to protect the safety during exercise. It is worth mentioning that if the EMG sensor is configured, the robot can also analyze the working status of the muscles in depth and provide users with more personalized exercise recommendations.In addition, the introduction of pressure sensors enables the robot to accurately evaluate the user's gait balance, further improving the safety and effectiveness of exercise. In the data processing link, the system combines advanced biomechanical models with deep learning algorithms.In particular, the variant of the BERT model is used to conduct in-depth mining and intelligent analysis of massive amounts of exercise data, so as to customize a more accurate and personalized training plan for users.At the same time, through fuzzy logic or rule engine technology, a complete health assessment system has been constructed, which can dynamically adapt to the user's health status and provide early warning and feedback in a timely manner. In terms of communication and control, the system makes full use of the latest wireless communication technologies, including Wi-Fi, Bluetooth, and 5G, to ensure real-time data transmission and processing.Through a highly integrated control unit, the robot can respond intelligently based on the data analysis results processed by the cloud or local algorithms.This includes providing users with instant feedback, guiding correct exercise skills, and conducting safety interventions when necessary, so as to improve the user's exercise experience and health management level in all directions.

In a health monitoring system that combines service robots and biomechanics, data processing is essential.First of all, incomplete or incorrect data records need to be eliminated, and the average value substitution method is used to correct the outlier.Next, a low-pass filter is used to remove high-frequency noise and retain key signals. In this paper, a digital low-pass filter is used to process acceleration data to reduce random vibration interference.In addition, in order to eliminate the dimensional differences between sensors, data normalization is also carried out. In this article, the minimum-maximum scaling technique is used.This series of treatments ensures the accuracy of monitoring and the provision of effective health recommendations.The equation is:

$$A_{norm} = \frac{A - A_{min}}{A_{max} - A_{min}} \tag{1}$$

among: A—Initial data;

A_{max}, A_{min}—Data maximum and minimum values.

Subsequently, the system extracts the characteristics that are closely related to sports performance and health status.The three-axis acceleration data is used to estimate the energy consumption during exercise, and the sum of squares of acceleration is used to approximate the overall amount of exercise. At the same time, continuous heart rate data is analyzed, and indicators such as standard deviation SDNN or RMSSD are calculated to reveal the activity of the autonomic nervous system and the ability to recover after exercise. From the collection and collation of raw data to the final analysis link, every step is committed to enhancing the practicality of the system and optimizing the user experience.

3.1.1. Physical fitness evaluation model

Biomechanical models are usually used to predict and analyze the mechanical properties of the human body during exercise, such as joint force and muscle activity. High-precision sensors (such as accelerometers, gyroscopes, and magnetometers) are used to collect data such as three-dimensional coordinates, speed, and acceleration when the human body is moving.Based on the principle of Newtonian mechanics, a dynamic model of human body movement is established, considering the mass, moment of inertia, joint constraints and other parameters of all aspects of the human body.Using known kinematics data (such as joint angle) and dynamics data (such as ground reaction force), optimization algorithms (such as gradient descent, genetic algorithms) are used to estimate model parameters, such as muscle activation patterns, joint moments, etc.

Divide the exercise intensity into n levels, record the amount of physical activity, and obtain a statistical function of the user's physical fitness:

$$f(x) = s(i) + \mu + e_k \tag{2}$$

$$f_j = \sum_{i=1}^{j} f(x) + [s(i) + e_k] \tag{3}$$

where $s(i)$ is the user's electrocardiogram evaluation parameter, μ is the weight index for the distribution of physical activity and fitness evaluation characteristics, and e_k is the user's motor function adjustable parameter during exercise.

Build a fuzzy decision-making function for user fitness evaluation:

$$G(\mu) = \frac{a_m + b_l}{Q} + (a_i + b_k) \tag{4}$$

In the equation, Q is the number of samples, and a_m, b_l, a_i, b_k are the observation set used for the user's physical fitness.

3.1.2. Motion data processing

Using three axis acceleration data to measure the amount of physical activity of a user during movement, first analyze the absolute accelerations of the three axes, including:

$$a_x = 0.8g_x + 0.2\lambda_x \tag{5}$$

$$a_y = 0.8g_y + 0.2\lambda_y \tag{6}$$

$$a_z = 0.8g_z + 0.2\lambda_z \tag{7}$$

where a_x, a_y, a_z represent the gravitational acceleration in the three coordinate axis directions at a given moment, g_x, g_y, g_z represent the gravitational acceleration at the previous moment, and λ_x, λ_y, λ_z represent the sensor output values in the three directions.

x, y, z are the absolute acceleration of the three axes, expressed as:

$$x = \lambda_x - a_x \tag{8}$$

$$y = \lambda_y - a_y \tag{9}$$

$$z = \lambda_z - a_z \tag{10}$$

3.1.3. Calculation of respiratory rate

Assuming that there is a queue m that stores the respiration rate data for a certain period of time, and the elements contained in the queue are x_1, x_2, ..., x_m, which correspond to the respiration rate at the time points t_1, t_2, ..., t_m, respectively, then the respiration rate at the time point t_m is:

$$P_m = \frac{x_m - x_1}{t_m - t_1} \tag{11}$$

where t_m represents the current moment, and since the user's actual respiratory rate does not mutate, the average respiratory rate within a time period is equivalent to the current respiratory rate.

3.2. Fitness evaluation standards in biomechanics

When the human body is at rest, various substances in the body are in a relatively stable and undisturbed state. Under sports or other conditions, due to the effects of external factors, the body would produce a series of changes, which often lead to a variety of physiological dysfunction. This includes shortness of breath, increased pulse, and elevated blood pressure, which affects health levels. Physical fitness is a reflection of the relationship between this functional abnormality and normal physiology. It is the ability of the body to adjust and regulate itself in a specific way to achieve its intended purpose. Physical fitness is a relatively large concept, which involves many fields such as physics, chemistry, biology, medicine, and sociology. According to different research objects, it can be divided into healthy fitness and competitive fitness. The former includes the regulation of physical functions in sports training, such as muscle strength, flexibility, body composition, and cardiopulmonary endurance. The latter refers to some physical skills, including explosive power such as speed and strength, as well as balance, coordination, and sensitivity. The specific evaluation criteria and training methods are shown in **Table 1**.

Muscle strength refers to the strength of muscles displayed by athletes when completing various movements, including the maximum strength that muscles can generate and the ability to continuously contract. It is generally exercised through weight training machines and dumbbell resistance training. Flexibility refers to the ability required for the relatively coordinated operation of various tissues and organs in the human body, and it is one of the essential basic conditions for the body to maintain normal physiological functions. Generally, stretching training, stretching exercises, yoga, and tai chi can all play a role in softening and shaping a beautiful body. Body composition refers to the composition and proportional relationship of various parts of the body, which not only reflects individual physical characteristics but also serves as one of the criteria for evaluating the effectiveness of physical training. It is of great significance to keep body composition within a normal percentage range for the prevention of certain chronic diseases such as diabetes, hypertension, arteriosclerosis, etc. Cardiopulmonary endurance, also known as aerobic endurance, refers to the mental state or behavioral tendency of an exerciser to withstand a certain intensity and frequency of physical activity and achieve a predetermined goal through continuous efforts. It is generally achieved through aerobic gymnastics, aerobic dance, rope skipping, cycling, swimming, combat training, and other sports forms.

Table 1. Evaluation criteria and classification of physical fitness.

	Classification	Evaluation criteria	Description
Physical fitness	Healthy physical fitness	Muscle strength	Weight training machine, dumbbell barbell resistance training
		Flexibility	Stretching, yoga, tai Chi
		Body composition	Component and proportion relation of each part
		Cardiopulmonary endurance	Aerobic gymnastics, aerobic dance, jump rope, bicycle, swimming, combat training
	Competitive fitness	Physical strength	Speed, strength, balance, coordination, agility

The physical fitness evaluation index is a diversified and deep-level system that comprehensively measures a person’s athletic ability and physical state from multiple angles.At the level of physical health, muscle strength evaluation occupies an important position, which usually involves strength testing of multiple muscle groups.Specifically, we will pass 1RM tests, such as squats and bench presses, to determine the maximum load-bearing capacity under specific movements, the so-called maximum strength.In addition, we will use the number of repetitions of weightlifting under a certain weight to assess the long-lasting working ability of the muscles, which is called endurance strength.Muscle endurance is tested by long-term light to medium-intensity activities, such as the length of time for flat support.

Flexibility is also a key part of the evaluation.We will measure the range of joint movement, which is the maximum angle at which a particular joint can rotate, such as the dorsiflexion of the ankle joint and the extension of the hip joint.At the same time, we will also pass dynamic stretching tests, such as leg swing tests, to evaluate the flexibility of muscles and joints in dynamic activities. Let’s take a look at the body composition. Body fat rate is an important indicator. We will use methods such as bioelectricity impedance analysis, skin pleat thickness measurement, or underwater weighing to estimate.Muscle mass can be evaluated by Dexa scanning, bioelectricity impedance and other techniques.The body mass index, or BMI, is calculated by dividing weight (kg) by the square of height (m) and is used to assess whether weight is within a healthy range.

In terms of cardiopulmonary endurance, we measure the maximum oxygen uptake, that is, the maximum amount of oxygen that the body can consume per minute during extreme exercise.At the same time, we will also indirectly evaluate cardiopulmonary endurance through running or cycling tests, such as the Bruce

Protocol running test, the Cooper 12-minute running test, or the power cycling test. In the evaluation of competitive physical fitness, we will pass sprint tests, such as the 100-meter sprint, to evaluate the top speed.

In terms of strength, we will conduct explosive strength tests, such as standing long jump and vertical jump tests, to measure the instantaneous maximum muscle strength output.The balance ability is evaluated by standing on one leg for a long time, standing with eyes closed, etc. Coordination tests include agility ladder test, hand-eye coordination racket hitting test, etc.

The sensitivity is evaluated through the T-word running test, the 5-0-5 agility test, etc. This evaluation system can reflect the individual's physical fitness in all directions and from multiple angles, and provide strong support for scientific training and healthy life.

3.3. Object

In order to ensure the scientific nature and effectiveness of this research, we specially selected students from the School of Physical Education as experimental subjects.Because of their high degree of sports participation and diverse motor skills, these students are of great significance for evaluating the monitoring performance of intelligent service robots in different sports environments.In terms of sample selection, we pay attention to the diversity of gender, age and sports specialties (such as running, swimming, taekwondo, basketball, etc.), aiming to make the research results more universal. During the screening process, we excluded students who had severe exercise restrictions or recent injuries to ensure that the health of all participants could withstand the amount of exercise required for the experiment.

We used a random number table or a computer random program to sort all potential participants, and randomly selected the first 300 students as research samples.This random process ensures that each student has an equal chance of being selected, thereby reducing the selection bias. Subsequently, we randomly selected 40 of these 300 students and divided them into two groups: the control group and the experimental group.The control group used traditional monitoring methods for flexibility evaluation, while the experimental group used intelligent service robots for the same evaluation.During the experiment, we strictly controlled various factors that might affect the flexibility measurement, such as test time, environment, and warm-up activities, to ensure the consistency of the experimental conditions.After the experiment, we recorded the test data of each student in detail, and used statistical software for in-depth data analysis to comprehensively evaluate the effectiveness and advantages of intelligent service robots in flexibility monitoring.This article conducts physical fitness monitoring for these students according to the physical fitness evaluation criteria, and evaluates their flexibility through sitting posture and forward flexion. The results are shown in **Table 2**.

Table 2. Flexibility assessment in two kinds of physical fitness monitoring.

Sports item	Number of people	Traditional monitoring mode（cm）	Intelligent service robot monitoring method（cm）
Run	73	12.1 ± 5	12.169 ± 5
Swim	67	15.3 ± 5	15.338 ± 5
Taekwondo	81	10.8 ± 5	10.872 ± 5
Basketball	79	14.4 ± 5	14.417 ± 5

As shown in **Table 2**, this article uses traditional monitoring methods and intelligent service robot based monitoring methods to assess the flexibility of athletes in four different events. Of the 300 students to be tested, taekwondo majors have the most students, with approximately 81 students, accounting for approximately 27% of the total. The number of people majoring in swimming is relatively small, only about 67, accounting for about 22.33% of the total number of people. The overall distribution of the number of people is relatively average and has strong representativeness. In the measurement of flexibility, the scores of students majoring in running monitored based on traditional methods are about 12.1 ± 5 cm, while the scores monitored based on intelligent robots are about 12.169 ± 5 cm. The data monitored by robots in swimming, taekwondo, and basketball are also more accurate than traditional methods. This shows that intelligent service robots can well meet people's needs for sports data, enabling sports workers to provide healthy sports to the public more comprehensively.

3.4. Result

According to the survey results of research objects, this article randomly selected 5 students from each sports project to design a comparative experiment, and obtained a total of 20 students as a sample. This article analyzes the monitoring effects of intelligent service robots before and after optimization from three aspects: work efficiency, comprehensiveness, and user experience. This article records and analyzes experimental data.

3.4.1. Work efficiency

Working efficiency is one of the most basic and effective management methods for measuring the effectiveness of monitoring. Using data acquisition equipment with high automation, simple operation, and good adaptability in the process of physical fitness monitoring is of great significance for improving detection efficiency. The comparison of work efficiency between traditional monitoring methods and robot monitoring methods is shown in **Figure 1**.

As shown in **Figure 1**, **Figure 1a** shows the work efficiency of traditional monitoring methods, and **Figure 1b** shows the work efficiency of robot monitoring mode.

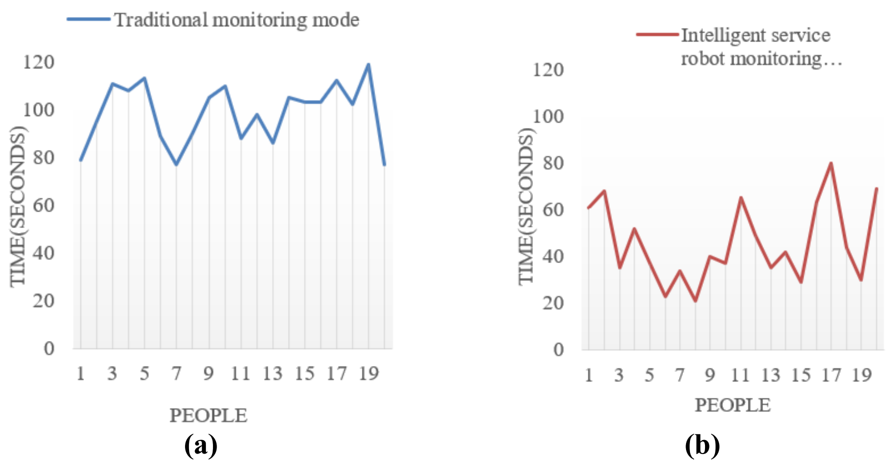


Figure 1. Comparison of work efficiency of two monitoring methods. **(a)** efficiency of traditional monitoring methods; **(b)** the working efficiency of the robot monitoring mode.

Figure 1a shows the efficiency of monitoring the physical fitness of 20 students using traditional methods. It can be clearly seen that the data range in Figure a is between 75 and 120 seconds, and it takes up to nearly 120 seconds, or 2 minutes, to complete the data collection and display work, with a minimum of about 75 seconds. The gap between students in different majors is also relatively large. It shows that traditional monitoring methods are inefficient and cannot meet the real-time monitoring requirements of complex and diverse, massive information, and dynamic changes in the current network environment.

Figure 1b shows the efficiency of monitoring the physical fitness of 20 students using a monitoring method based on intelligent service robots. This group of data fluctuates more widely, indicating that the robot based body fitness monitoring method is not mature enough and still needs to be optimized to achieve stability. The data range in **Figure 1b** is between 20 and 80 seconds, with individual students' monitoring time exceeding 50 seconds. The data in the figure is prominent, but most students' monitoring time is distributed between 20 and 50 seconds, which is far lower than the data in **Figure 1a**.

Looking at the two sets of data in **Figure 1**, it is found that the monitoring method based on intelligent service robots generally consumes less time and is more efficient. At the same time, it is also characterized by strong real-time and easy to expand, and has a wide range of application scenarios.

3.4.2. Comprehensiveness

The more comprehensive the monitoring scope, the higher the quality of the obtained data, and the more accurate analysis and targeted prediction can be made. This article compares the comprehensiveness of the two monitoring methods based on the size of the monitoring range. Each successful completion of the monitoring evaluation of a data item is recorded as a score, and the results are shown in **Figure 2**.

As shown in **Figure 2**, **Figure 2a** shows the comprehensiveness of traditional monitoring methods, and **Figure 2b** shows the comprehensiveness of robot monitoring methods.

Figure 2. Comprehensive comparison of two monitoring methods. **(a)** the comprehensiveness of traditional monitoring method; **(b)** comprehensiveness of robot monitoring method.

Figure 2a shows the monitoring scores of these 20 students based on traditional methods. The scoring range in **Figure 2a** is from 1 to 10 points, with an average score of about 5.75 points. It is at a moderate to lower level, making it difficult to accurately locate and track moving targets, so it cannot achieve complete and accurate trajectory parameter descriptions and other functions.

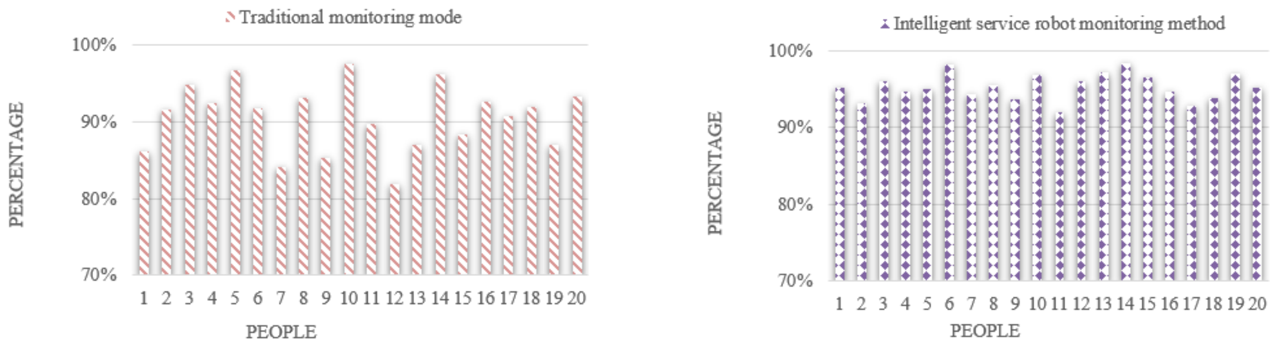
Figure 2b shows monitoring scores based on robot monitoring methods, with a score range of 3–15 points. The average score is around 8.05, which is much higher than that in **Figure 2a**. Therefore, the optimized fitness detection system based on intelligent service robots is more accurate and comprehensive, and can achieve better state perception effects.

It can be seen that the data trend of both groups of histogram is not stable, indicating that due to factors such as environment and equipment, there are certain limitations in monitoring methods, which still need to be optimized.

3.4.3. User experience

The 20 invited students were asked to rate the experience of the two monitoring methods, and the results are shown in **Figure 3**.

As shown in **Figure 3, Figure 3a** shows the experience level of traditional monitoring methods, and **Figure 3b** shows the experience level based on robot monitoring.



(a) **(b)**

Figure 3. Comparison of user experience between two monitoring methods. **(a)** experience degree of traditional monitoring method; **(b)** experience degree based on robot monitoring method.

Figure 3a shows the user experience rating results based on traditional methods. The lowest score in **Figure 3a** is about 81.89%, and the highest score is about 97.55%. The data fluctuates greatly. It shows that traditional intelligent monitoring systems require human participation and the working environment is relatively complex, which is easily affected by environmental changes, resulting in a decline in accuracy and affecting the sense of experience.

Figure 3b shows the user experience rating results based on robot monitoring. The data is more centralized, and all exceed 90%. It is able to better complete the analysis and evaluation of health conditions under the adaptive state of physical fitness. It also has certain practicality and feasibility, and has a positive role in enhancing people's physical fitness and preventing diseases

After calculation, the average user experience based on traditional methods is about 90.64%, and the average user experience based on intelligent service robots is about 95.32%. The user experience of the improved monitoring system has increased by about 4.68%.

3.5. Discussion

Through the above research, we found that intelligent service robots are significantly better than traditional methods in monitoring efficiency and take less time, which shows the significant improvement of robotics in data acquisition and processing speed.This is mainly due to the automation, real-time response and efficient data transmission of the robot system, which reduces the time loss of human operation. It is essential for scenarios that require rapid feedback, such as intensity adjustment in sports training and medical emergency response. At the same time, the intelligent robot monitoring method also greatly surpasses traditional methods in terms of comprehensiveness, and can more widely cover and accurately evaluate various physiological indicators.This is due to the robot's ability to integrate multiple sensor data and use complex algorithm models for in-depth analysis to provide a more detailed description of the health status.For example, in addition to accurately measuring flexibility, the robot can also monitor heart rate, breathing rate, etc., providing strong data support for the development of personalized training programs. In addition, the significant improvement in user experience shows that intelligent service robots have made substantial progress in interactivity, ease of use and user satisfaction.The robot can adjust the monitoring strategy in real time based on user feedback and provide personalized recommendations. This interactive experience enhances the user's sense of participation and trust, and helps to promote long-term healthy behavior changes.

However, the research also found that there are certain fluctuations in the robot monitoring data, indicating that the stability of the system needs to be strengthened.Environmental factors, individual differences, or equipment errors may be the cause of data fluctuations, so more accurate calibration and algorithm optimization are required.At the same time, although the robot monitoring method is superior to traditional methods in comprehensiveness and efficiency, the technology is still maturing, especially in dealing with complex motion patterns and individual specificity.This means that future technological improvements and algorithm iterations are essential. In addition, the high cost of research and development and application of intelligent service robots may limit their popularity among large-scale populations.Therefore, future research needs to focus on how to reduce costs and improve the accessibility and penetration of technology. Looking to the future, combining cutting-edge technologies such as biomechanics, the Internet of Things, and cloud computing, we can explore more multi-dimensional health monitoring, such as mood monitoring and sleep quality assessment, in order to achieve more comprehensive health management.At the same time, research should continue to deepen the intelligent recognition of user behavior patterns and develop more refined personalized health promotion plans to meet the health needs of different groups of people.Long-term follow-up research will help to comprehensively evaluate the actual effect of intelligent health monitoring systems and provide strong empirical support for the effectiveness of the technology.

4. Implementation of motion monitoring system based on service robots and biomechanics

4.1. Process biomechanics-based physical activity measurement process

Biomechanics measurement is one of the most effective methods for fitness evaluation. After high-intensity physical training, individuals often experience muscle fatigue or joint pain. This necessitates a series of functional movement tests to determine the presence of exercise-induced injuries or potential risks, allowing timely interventions to control and mitigate the progression of such injuries [24].

Biomechanics-based physical activity measurement is grounded in the functionality of the musculoskeletal system. It records biomechanical changes and patterns that occur in the body during various activities. This method not only reflects the general state of physical function and athletic performance but also serves as a critical indicator for identifying the occurrence, progression, and recovery of sports injuries. Its applications include recording the movements of joints and muscles, diagnosing sports injuries, identifying muscle strength imbalances and joint abnormalities, assessing athletic techniques and training outcomes, and evaluating rehabilitation progress and fitness levels.

With advancements in health science and improvements in living standards, more people recognize that maintaining good health requires scientific exercise and fitness training. The combination of intelligent health service robots and biomechanics measurement technology allows for more precise monitoring and evaluation of an individual's physical activity and fitness status, providing strong support for scientific fitness and injury prevention.

4.2. Implementation of machine human fitness monitoring system

With the increasing importance that humans attach to their own health and the development and progress of social and economic levels, people gradually realize that health is not only related to the quality of life, but also affects the harmony and stability of the entire society. Aiming at the problems of traditional methods in the field of body fitness monitoring that cannot achieve precise control, accurate positioning, and complex motion trajectory recognition, this paper proposes an intelligent monitoring system for body fitness based on intelligent service robots. The system applies biological information collection technology to motion state perception. In this paper, a user behavior model is established based on the body data obtained by sensors and related parameters. Through big data analysis, the required motion patterns of the human body in different scenarios are determined, thereby providing personalized motion guidance for individuals, as shown in **Figure 4** for details.

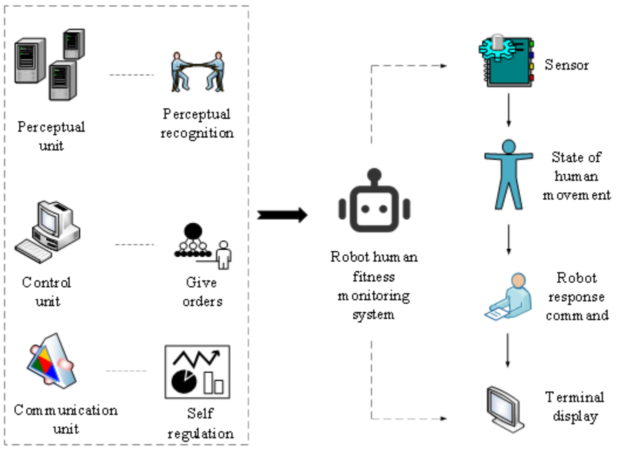


Figure 4. Implementation of the robot body fitness monitoring system.

The intelligent service robot is a hardware device composed of a sensing unit, a control unit, and a communication unit. Its core part is a perception module, which can sense the actions of people or objects in real time without human intervention, and communicate with the external environment. The communication unit is the center of the device, which plays a role in connecting various functional components. The system uses tag recognition technology, sensor networks, and wireless communication technology as the main communication means. It uses sensors to measure changes in the position of the body, thereby achieving the goal of automatically adjusting its posture. The control unit is the brain of the entire device, responsible for executing instructions in the control system, enabling the robot to make corresponding operations according to specific procedures. It mainly includes power management chips and processors.

The process of robot fitness monitoring is as follows: Firstly, it uses sensors to obtain human motion status, such as posture or motion mode. Target objects are identified based on their characteristics, and on this basis, it is determined whether intervention is necessary. It then transmits the collected data to the server through wireless transmission, which then returns it to the intelligent terminal to ensure that the robot can accurately respond to instructions, thereby achieving real-time monitoring of the environment and human physical condition. Finally, the collected information is processed and displayed by the intelligent terminal for user query and analysis, completing the entire process of physical fitness monitoring. The system is a new intelligent detection device based on an embedded platform that integrates computer vision technology and biosensor technology. It has the advantages of strong real-time performance, high anti-interference ability, simple operation, reliable operation, and easy maintenance. It is suitable for various occasions of physical fitness testing work [25].

The application of robotics in physical activity and health monitoring faces many challenges.First of all, it is necessary to reasonably integrate and optimize high-precision sensors to ensure that they can accurately capture small changes in human movement, while having strong anti-interference capabilities and stable and reliable data acquisition capabilities.Secondly, the development of complex algorithmic models is also an important task, including accurate biomechanical models and machine learning algorithms that can effectively process big data to achieve personalized exercise guidance and health prediction, which requires a high degree of customization and continuous optimization of algorithms. In addition, real-time data processing and transmission are also a challenge, especially in high concurrency scenarios, it is necessary to efficiently process sensor data and upload it to the cloud in a timely manner. This puts forward high requirements for back-end analysis systems, and data latency and bandwidth utilization must be solved.At the same time, robots need to have a friendly and natural user interface, be able to adjust services based on user feedback, and respond quickly in emergency situations to improve the user experience. In addition, security and privacy protection are also issues that cannot be ignored. It is necessary to ensure user privacy and security during data collection and processing, and strictly prevent data leakage.Finally, robots need to have good adaptability and stability, be able to work stably in various sports environments and individual differences, and have environmental adaptability and self-healing ability.These technical problems require interdisciplinary cooperation, continuous promotion of technological innovation and system integration, in order to provide smarter and more efficient health monitoring services.

5. Conclusions

Monitoring and analyzing muscles, joints, and other parts in human motion is a complex and difficult system engineering. Due to limitations in instrumentation, data collection methods, and data processing software, most researchers currently focus on qualitative analysis and quantitative analysis in the research process. Based on intelligent service robot technology, this paper designed and implemented an online monitoring system for intelligent mobile terminals. The system can detect the actions required by users in real time, and send the monitoring results to the background server through the network, thereby achieving intelligent control. It can provide users with real-time and dynamic health status information and personalized suggestions, thereby achieving the goal of improving work efficiency and reducing operating costs. Starting from the evaluation criteria for physical fitness, this paper proposed a monitoring system for physical fitness based on intelligent service robots to address the shortcomings of existing monitoring systems that cannot accurately reflect the actual physical health status of individuals. This article described the overall structure and working principle of the system in detail, focusing on the design principles of the system platform architecture, sensor module, communication module, database management system, and human-computer interaction interface, as well as the specific implementation methods of the main functional modules. Finally, a comprehensive service platform integrating hardware device management, data analysis and calculation, and remote diagnosis guidance was built. This can effectively improve the monitoring level and service quality, meet customer needs, and achieve good application results.

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