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Physical exercise rehabilitation system based on internet of things and big data technology

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Abstract. With the combination of big data technology and the Internet of Things and exercise rehabilitation, we are also facing the problem of processing massive amounts of data. Whether these data can be used well has become the key to obtaining good business benefits and improving user experience. This paper applies the Internet of Things and big data technology to the physical exercise rehabilitation system to improve the sports data processing and combine with the big data processing technology to explore the factors affecting the effect of exercise rehabilitation to improve the effect of physical exercise rehabilitation. Moreover, this paper proposes a posture recognition algorithm based on human vision, and defines the human posture described by the feature, which improves the classifier's ability to classify different posture data. Finally, this paper combines experimental analysis to verify the effect of the method in this paper. From the research results, it can be seen that the method constructed in this paper has a good rehabilitation effect of physical exercise.

Keywords: Internet of Things; big data; physical exercise rehabilitation; intelligent system

1. Introduction

With the acceleration of modernization and urbanization, people's physical condition is declining year by year, and the current situation is worrying. However, in the process of urbanization, more and more people are also paying attention to the importance of health and starting physical exercise rehabilitation. However, as people continue to over-exploit nature, the natural environment is deteriorating day by day, the living environment is deteriorating, and the air quality has not improved, which casts a shadow on outdoor exercise rehabilitation. Moreover, due to traffic jams and the lack of maturity of the civilized consciousness of motor vehicles, it is difficult to guarantee the safety of people in outdoor activities. Therefore, indoor sports exercise rehabilitation equipment slowly began to enter people's homes [1].

At present, the development status of my country's exercise and rehabilitation industry is not optimistic. Moreover, most of the domestic exercise and rehabilitation places still use outdated management methods, and the management concepts are relatively backward. As a result, the management of exercise and rehabilitation places is extremely cumbersome and inefficient, which is not conducive to its long-term development, and it is not conducive to the good development of exercise rehabilitation industry in our country [2]. Therefore, it is necessary to use efficient and convenient management methods to change the current situation of the exercise rehabilitation industry in my country and promote the rapid development of exercise rehabilitation industry.

In the exercise rehabilitation industry, in recent years, more and more people have begun to like exercise rehabilitation and joined the team of exercise rehabilitation. Therefore, exercise rehabilitation has become a trend and a new way of life. The country is also paying more and more attention to people's exercise rehabilitation. The State Council's No. 46 document raised national exercise rehabilitation to the height of the national strategy, requiring vigorous development of exercise rehabilitation leisure projects. Moreover, it creates an atmosphere of exercise rehabilitation, encourages exercise rehabilitation activities, and promotes the sports industry to become an important force in economic transformation and upgrading [3].

When exercise rehabilitation hits "Internet +", a new model of exercise rehabilitation will surely appear. "Internet + exercise rehabilitation" is a new type of exercise rehabilitation method that has emerged in this context. In the era of "Internet +", the scale of application data generated by all walks of life has shown explosive growth, and more and more enterprises are facing the problem of handling massive amounts of data. The combination of exercise rehabilitation and Internet+ will inevitably generate massive application data. Big data platforms are bound to analyze and process these massive exercise rehabilitation data to obtain the information hidden behind these data. With the spread of big data ideas, more and more companies are beginning to realize that these massive amounts of data contain rich knowledge. Through the analysis and processing of massive amounts of data, the value hidden behind the data can be unearthed. In the exercise rehabilitation industry, with the combination of "Internet +" and exercise rehabilitation, it is also faced with the problem of processing massive amounts of data. Whether these data can be used well has become the key to obtaining good commercial benefits and improving user experience.

Traditional exercise rehabilitation mode information is closed, it is difficult for users to obtain exercise rehabilitation information, and the exercise rehabilitation data of users is not fully utilized. In today's society, people use various smart devices to record their own sports information, such as Xiaomi's "smart bracelet", WeChat's "WeChat sports" and QQ's "sports platform". The popularity of "Internet +" has changed people's access to information. The way of exercise and rehabilitation, the exercise rehabilitation APP is the perfect embodiment of "Internet + exercise rehabilitation". Nowadays, mobile smart phones are popular, and more and more people are accustomed to using exercise and rehabilitation apps to help them exercise and recover. Some high-quality exercise and rehabilitation apps such as "Gudong Sports" and "Keep" have tens of millions of users and walk into any one. In the exercise rehabilitation room, you can see that many users are doing exercise rehabilitation training following the APP video tutorials. While these exercise and rehabilitation apps provide rich functions, there are also some problems and areas that can be improved: First, the exercise and rehabilitation apps on the market now only obtain content from the server and display it to the user. The user is on the exercise rehabilitation equipment. The generated data cannot be obtained, that is, data interaction with exercise rehabilitation equipment cannot be performed. Second, there is no real real-time update in the real-time update of data.

Based on the above analysis, this paper applies the Internet of Things and big data technology to the physical exercise rehabilitation system to improve sports data processing, and combines big data processing technology to explore the factors affecting the effect of exercise rehabilitation to improve the effect of physical exercise rehabilitation.

2. Related work

The United States, as the first country to study physical fitness, generally adopted physical fitness tests in the 1880s. It was not until 1954 that Kraus compared the physical test data of American children with that of European children before bringing the physical test into the eyes of the public. What is surprising about the results of this comparative test is that the physical fitness of American children is significantly weaker than that of European children. This unexpected result attracted strong attention from all walks of life at that time. Moreover, the result was described by the media as "a report that shocked the president." At that time, President Eisenhower attached great importance to this, and therefore set up the Presidential Committee of Youth Constitution to coordinate the development of youth physique nationwide. Therefore, physique research has changed from obscurity to the focus of national attention [4]. In 1958, AAHPERD (American Alliance for Health, Physical Education, Recreation and Dance) conducted the first nationwide youth physical fitness survey with the funding of the University of Michigan. Later, with the funding of the Federal Office of Education, AAHPERD conducted physique surveys of young people across the United States in 1965 and 1975 respectively. In 1985, PCPFS (President's Council on Physical Fitness and Sports) conducted a physical fitness survey of all school personnel nationwide with the funding of the Federal Department of Health [5]. Regarding the physical fitness research of young people, in addition to the various physical fitness tests in school sports, there are also regional censuses in different places, and there is also a national youth physical census every ten years. In short, the physical research work in the United States is highly targeted and planned. In terms of physical fitness assessment methods, the original Kraus-Weber test failed to cover all the content involved in the physical fitness test [6]. Then, AAHPERD proposed a test method involving 7 indicators, but all the indicators in this method are sports indicators, and there is no related indicators related to health status [7]. In subsequent national censuses, physiological indicators representing health gradually replaced indicators showing exercise ability. By the early 1990s, the physiological index representing health had completely replaced the physiological index representing exercise ability in physical fitness assessment. It can be seen from the development of physical fitness research in the United States that the focus of physical fitness research has gradually changed from athletic ability to health status [8]. This shows that the United States has changed its understanding of the concept of physique, which has closely linked physique and health, and eventually developed it into a scientific discipline. Japan is also a country with relatively early research on physical fitness [9], and it has preserved all the growth and development data of all adolescents and children since 1898. Beginning in 1879, Japan has conducted surveys on adolescents' physical exercise ability, involving 8 physiological indicators of physical structure and exercise ability. On the eve of World War II, Japan conducted the largest national physical examination in history. Then, during the ten-year period beginning in 1949, all students nationwide were tested 5 times in terms of athletic ability, strength, and flexibility. Beginning in the 1970s, with the continuous improvement of technological level and increasing economic strength, Japan has strengthened its investment in national fitness testing, and formulated different physical testing plans for people of different ages. Japan began to conduct physical tests on national citizens in 1967, and the Ministry of Education, Culture, Sports, and Culture dispensed with issuing the annual "Physical Strength and Athletic Ability Report" and evaluated the quality of physical fitness based on the test results. At the same time, it worked out corresponding exercise prescriptions for targeted exercise rehabilitation [10].

The literature [11] combined fuzzy comprehensive evaluation and analytic hierarchy process to test athletes' physical fitness. The evaluation model can reflect the specific physical fitness level of the athletes actually tested, and obtain scientific and reasonable evaluation results. The literature [12] used fuzzy comprehensive evaluation to comprehensively evaluate the physical fitness of Chinese adolescents from three main influencing factors and four aspects of cultivation. The literature [13] used the fuzzy comprehensive evaluation method to divide the physical fitness into four aspects: speed, endurance, agility, and flexibility to comprehensively evaluate the differences in physical fitness of each person. The literature [14] used a clustering method to analyze the physical fitness test results of college freshmen, and puts forward constructive opinions from multiple aspects based on the analysis results. The literature [15] used backpropagation neural network to evaluate the fitness effect of women aged 20 to 65. The error between the accuracy of the evaluation result and the actual test result is only 3.28%. The literature [16] combined fuzzy comprehensive evaluation with neural network and objectively evaluated the 100-meter race with the ability to describe sports and achieves the desired accuracy. The model can be used not only to simulate and predict sports performance, but also to provide quantitative criteria for athlete selection. The neural network model established in the literature [17] realized the prediction of adult gender, age, weight, steady-state heart rate, running speed and maximum oxygen uptake of exercise. The prediction result is more accurate than the prediction result of multiple linear regression analysis. At present, the physiological indicators involved in the physical fitness assessment methods adopted by our country for citizens mainly include three physiological indicators of human body shape and structure, body function and basic quality. The physical fitness assessment method adopted is a comprehensive score for the average weight of each index.

3. Physical exercise vision algorithm based on human vision

The human visual system is composed of the visual central nervous system of the eye and the brain, which mainly includes the eyeball, retina, lateral knee and visual cortex, as shown in Figure 1[18].

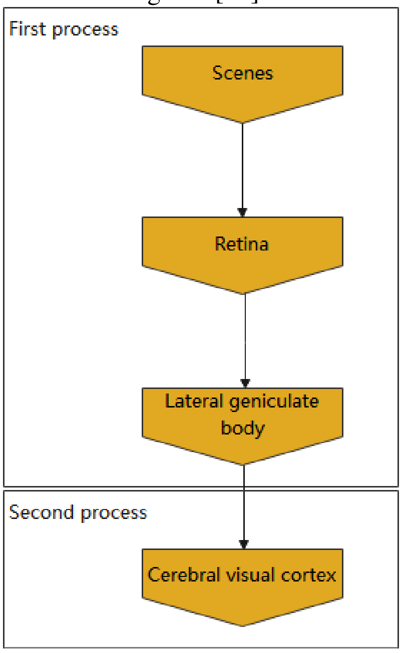

Figure 1 Block diagram of human visual perception system

Various objects in nature emit light or reflect light, and the optical processing of the human visual perception system is mainly completed by the eyeball. Natural objects use light as a carrier to enter the eyeball, pass through the lens and cornea to form a light signal that is transmitted to the retina. The photoreceptive cells on the retina perform a series of physical and chemical transformations on the received light signals, convert them into bioelectrical signals, and complete the primary processing of visual information. The image of the scene (inverted image) is presented on the retina, which is then transmitted to the lateral geniculate body. The lateral geniculate body is a transfer station responsible for controlling the amount of information allowed to pass. The lateral geniculate body responds and processes the received information, and then transmits it to the visual cortex of the brain. The visual cortex of the brain mainly completes the advanced processing of visual information and is the most complicated part. Visual information is comprehensively analyzed through the analysis, judgment, and memory of the visual cortex of the brain to produce vision (upright three-dimensional image). The above-mentioned entire processing process of visual information from the human eye to the brain is very complicated, but on the whole, it is a process that progresses from simple to complex, from low-level to high-level.

For images, the features of the human visual system mainly include brightness sensitivity, frequency sensitivity, multi-channel decomposition and masking effects.

(1) Brightness sensitivity

The relative brightness increment ΔB can be used to measure the brightness perception increment ΔS, as shown in the following formula[19]:

$$\Delta S = K\frac{\Delta B}{B} \quad (1)$$

In the formula, B represents objective brightness.

The perceived brightness can be obtained by integrating the above formula, as shown in the following formula:

$$S = K\,\mathrm{lnB} + \mathrm{K}_0 = K'\lg B + K_0 \quad (2)$$

Among them, K'= K Ln10, and K is a constant. K is a constant, and its value is related to the average brightness of the image. In the normal brightness range of the human eye, the value of K can be set to 1. According to formula (2), it can be seen that the human eye's subjective perception of the brightness S of the image is linear with the logarithm of the actual brightness B of the image, which is the basic content of the Web-Fechner law.

(2) Frequency sensitivity

Frequency sensitivity is usually expressed by the Contrast Sensitivity Function (CSF), which reveals the sensitivity of the human eye to sine wave stimuli of different frequencies. The frequency response formula of a relatively common human visual system is as follows[20].

$$H(w) = (a + bw)\ exp(-cw) \quad (3)$$

Among them, w is the radial frequency directly opposite the viewing angle, the unit is cycle/degree, and a, b, and c are three constants that determine the shape of the human visual system curve.

(3) Multi-channel decomposition and masking effect

The multiple channels of the visual mechanism interact and influence each other, so that the visual effect produced is the best. The multi-channel decomposition characteristics of a static gray image are characterized by spatial frequency and direction characteristics.

For the masking effect, the definition in the literature is quoted here. The literature points out that the masking effect is a visual phenomenon: the positive presence of one visual information will overwhelm or conceal another visual information that can be perceived, making it impossible or difficult to be detected at all.

Scholars' research on the human visual system attempts to model the visual perception characteristics of the image content of the human eye to simulate the entire processing process of visual information from the human eye to the brain. The main application of the human visual system is to measure the quality of the image. The quality of the image mainly includes the fidelity and intelligibility of the image. The HVS-based image quality evaluation uses a mathematical formula model instead of the human eye to objectively evaluate the quality of the image. The more consistent the quality evaluation of the image is with the subjective evaluation of the image by humans, the human visual system based on the human visual system model reflects the human visual system. The more real it is[21].

The basic framework of the traditional HVS model is shown in Figure 2. The framework includes five parts: brightness adaptability, multi-channel decomposition, contrast sensitivity function, masking effect and error merging. These five parts reflect the whole process of natural images being processed by human eyes and brain to form neural images, and they are related in sequence.

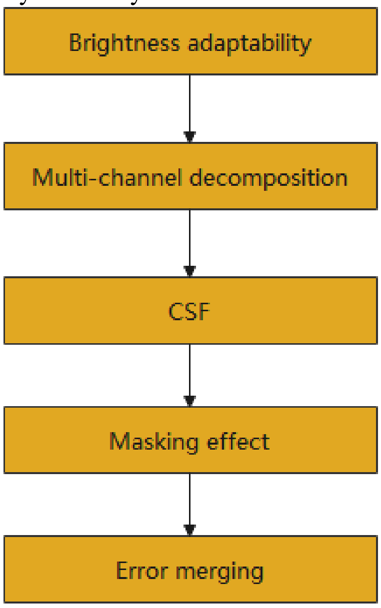

Figure 2 Typical HVS model framework

Figure 3 is a block diagram of the VDP model. It can be seen from the figure that the specific implementation process of the VDP model is slightly more complicated than that in Figure 3, but it basically follows the five steps in Figure 2.

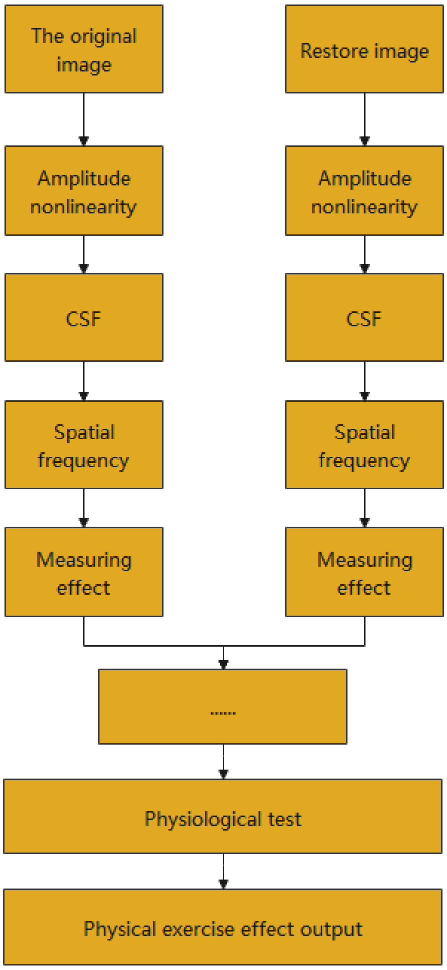

Figure 3 VDP model

Blocked DCT is used to replace the multi-channel decomposition in the human visual system model, which combines contrast sensitivity, masking effect and error merging. When the Watson vision model is used for image quality evaluation, the measurement of the difference between the original image and the distorted image is more in line with the subjective measurement of human perception of the distance of the image[22].

The brightness masking threshold is related to the DC coefficient of each image block and the contrast sensitivity table. For each DCT block, the calculation of its brightness masking threshold is shown in the following formula:

$$t_{L_{i,j}} = t_{i,j}\left(\frac{C_k}{\overline{DC}}\right)^a \quad (4)$$

Among them, $t_{i,j}$ is the value of JND in Table 1, C_k is the DC coefficient of the current DCT block, $\overline{DC}$ is an expected display brightness, or the average value of the DC coefficients obtained by DCT transformation of all block images of the original image. Under normal circumstances, a=0.649.

From formula (4), it can be seen that the relatively bright area in the image can tolerate a larger modification change.

(3) Contrast masking

For each DCT block, the calculation of its contrast masking value is shown in the following formula:

$$t_{C_{i,j}} = \max\left\{t_{L_{i,j}}, \left|DCTcoef_{i,j}\right|^{w_{i,j}} \bullet t_{L_{i,j}}^{1-w_{i,j}}\ \mathrm{j}\right\} \quad (5)$$

Among them, $t_{L_{i,j}}$ represents the brightness masking threshold, $w_{i,j}$ is a constant, and its value is affected by the frequency coefficient, and the value of $w_{i,j}$ is different when the frequency coefficient is different. Generally speaking, $w_{0,0}$ = 0, and the value of the remaining $w_{i,j}$ is taken as 0.7 (all the values of $w_{i,j}$ can also be taken as 0.7).

$DCTcoef_{i,j}$ is the DCT coefficient of the image block. It can be seen that the contrast masking threshold calculated according to formula (5) is a maximum operation, which is the larger of the product of the brightness threshold and the DCT coefficient adjusted by $w_{i,j}$ and the brightness threshold adjusted by $1-w_{i,j}$. The contrast masking threshold $t_{C_{i,j}}$ indicates the adjustable size of each item in the DCT coefficient of each image block within a JND range.

(4) Error combination

The Watson vision model uses Minkowski and error merging for each individually adjustable element in the DCT space. The calculation of the perceptual difference $\mathrm{d}_{i,j}$ of the image in the unit of JND at the (i, j)-th frequency is shown in the following formula:

$$\mathrm{d}_{i,j} = E_{i,j} / t_{C_{i,j}} \quad (6)$$

Among them, E is the error image obtained from the difference of the DCT coefficients of the original image test image. It can be seen that $\mathrm{d}_{i,j}$ is a value in ND, and the image quality evaluated is inversely proportional to the value of $\mathrm{d}_{i,j}$. The smaller the value of $\mathrm{d}_{i,j}$, the higher the image quality. The error combination using Minkowski sum is shown in the following formula:

$$D(I_o, I_w) = \left(\sum_{i,j} |d_{i,j}|^{\beta} \right)^{\frac{1}{\beta}} \quad (7)$$

Among them, the value of β is taken as 4.

The general human visual system model divides different spatial frequency bandwidths and observation angles as different channels. The difference is that the Watson visual model treats each DCT block in space as a separate visual channel.

The human visual system is highly complex and highly non-linear, but most methods only use linear or approximately linear methods to model the human visual processing mechanism. Wang et al. believe that the pixels of natural images are not independent of each other, but have an association relationship, which is more strongly reflected in spatially adjacent pixels. This strong correlation between pixels preserves the important structural relationship between the object and the background in the image. The structure information of the objects in the image scene has nothing to do with the brightness and contrast of the image. Based on this understanding, the structure of the visual model is shown in Figure 4.

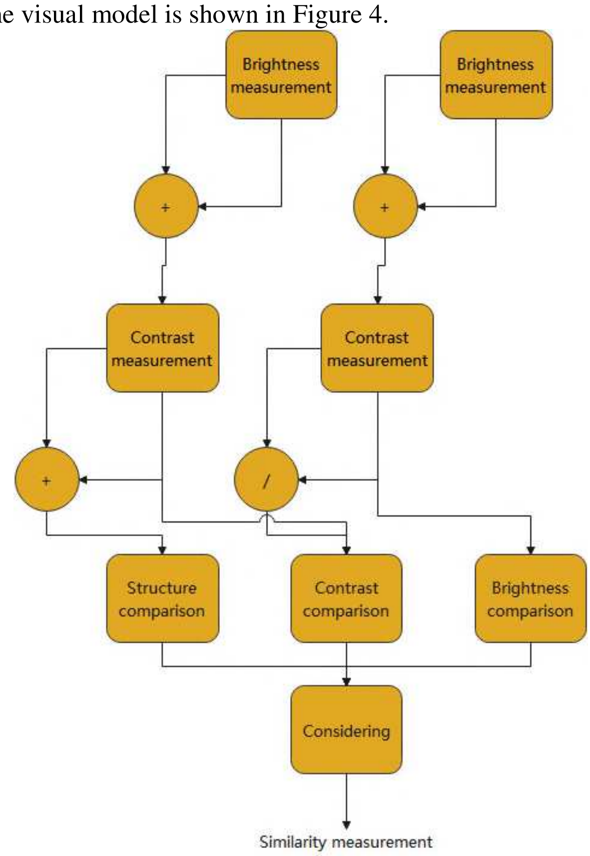

Figure 4 SSIM model

In the SSIM model, the constituent elements of image structure information include brightness, contrast, and structure. If it is assumed that the original image signal and the distorted image signal are x and y, respectively, the similarity measurement of x and y is:

$$S_{SSIM}(x,y) = [l(x,y)]^{\partial} [c(x,y)]^{\beta} [s(x,y)]^{y} \quad (8)$$

Among them, α, β, γ> 0 are the weight adjustment parameters. l(x,y) is the brightness comparison function, c(x,y) is the contrast comparison function, and s(x,y) is the structure comparison function. The specific definitions of these three functions are:

$$l(x,y) = \frac{2\mu_x \mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1} \quad (9)$$

$$c(x,y) = \frac{2\sigma_x \sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2} \quad (10)$$

$$s(x,y) = \frac{\sigma_{xy} + C_3}{\sigma_x \sigma_y + C_3} \quad (11)$$

μ_x and μ_y are the mean values of signals x and y respectively, which reflect the brightness information. σ_x and σ_y are the standard deviations of the signals x and y, respectively, reflecting the contrast information. σ_{xy} is the covariance of signals x and y, which reflects the similarity of their structural information $C=(K_1L)^2$, $C_2=(K_2L)$, $C_3= C_2/2$, $K_1 << 1$, $K_2 << 1$, where L is the dynamic range of the pixel value. For an 8-bit grayscale image, L=255.

The measure Q of the overall image quality is the average of the evaluation measures of all the pixel signals in the image. The quality of the test image is directly proportional to the value of Q. The larger the value of Q, the better the quality of the test image.

$$Q_{SSIM}\left(X,Y\right)=\frac{1}{M}\sum_{j=1}^{M}S_{SSIM}\left(x_j,y_j\right) \tag{12}$$

Among them, M is the total number of pixels in the image.

4. Physical exercise rehabilitation system based on Internet of Things and big data technology

This article uses the sensors on the fitness equipment to detect the user's exercise data and power generation, and writes the data into the NFC chip on the fitness equipment, and reads the data from the NFC chip through the mobile application APP with NFC function and uploads it to the cloud server. Users can check fitness data, power generation and historical data at any time through the APP, and can ensure the real-time update of data through WebSocket instant messaging technology, so as to realize the combination of "Internet +" and fitness. The structure diagram of the design idea is shown in Figure 5.

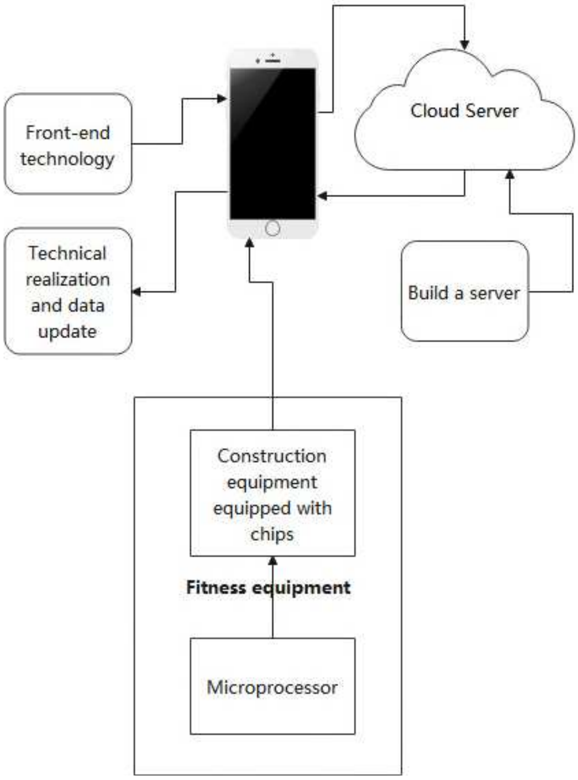

Figure 5 The structural block diagram of the design idea of the "Internet + fitness" system

Each device adds an offset value to the estimated clock to keep it consistent with the master device clock, so as to achieve the effect of synchronization. Moreover, a channel is shared between piconet networks, and the constituent members communicate through the channel. The connection of multiple piconet master devices forms a scatternet, and communication between the piconets can be realized. The roles of the master device and the slave device can be exchanged, forming a larger communication range. However, the formation of the scatter network is not unlimited, and the frequency limit can only achieve the connection between 10 piconet units. Figure 6 shows the structure of the scatter net.

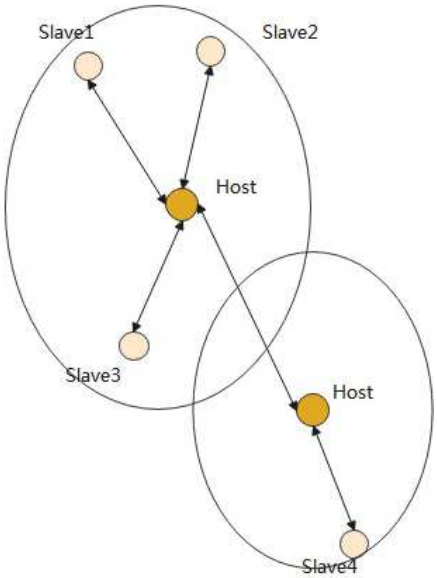

Figure 6 The structure of the scatter net

The user logs in to the system through a browser or WeChat program, and the accessed URL is resolved by DNS domain name to find the corresponding server host. The request will be intercepted and received by Tomcat in the server, and then handed over to the system software processing layer. After authentication and authorization, the business logic requested by the user is processed. The overall architecture process is shown in Figure 7.

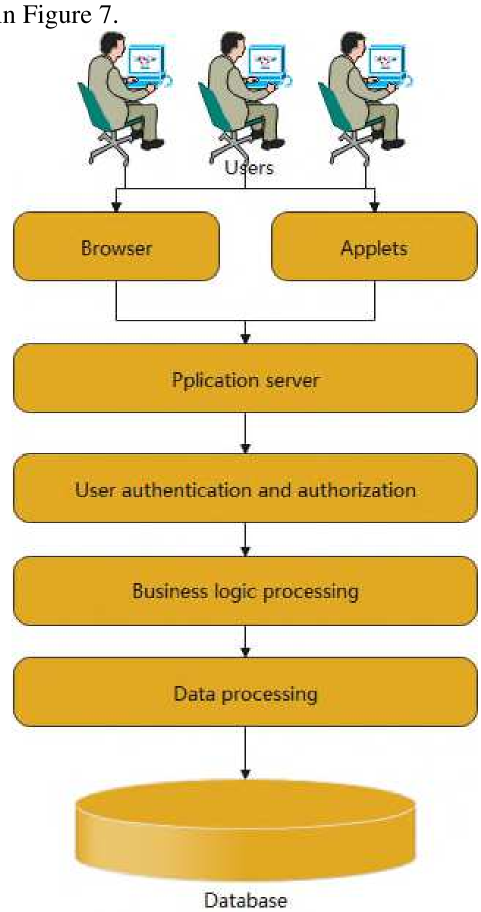

Figure 7 System architecture flow chart

The rehabilitation system constructed in this paper can adjust the physical state of the human body, and can also adjust the local injury of the human body, as shown in Fig. 8 is a schematic diagram of lower limb physical exercise.

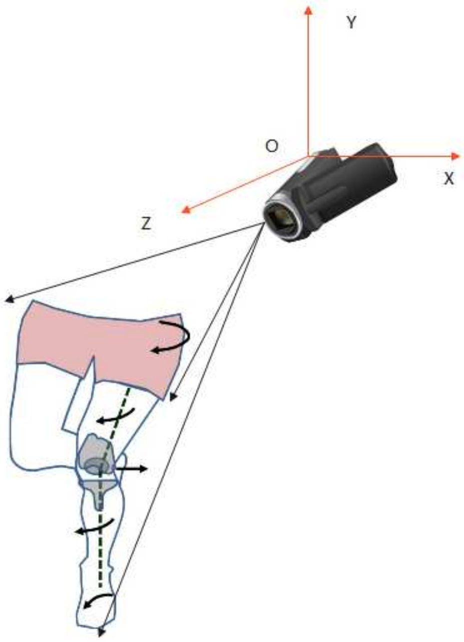

Figure 8 Schematic diagram of lower limb physical exercise rehabilitation

This article systematically studies the recovery process of lower extremity physical exercise, and takes the injury of the lower extremity as an example. Figure 9 shows the schematic diagram of the recognition of lower limb injury.

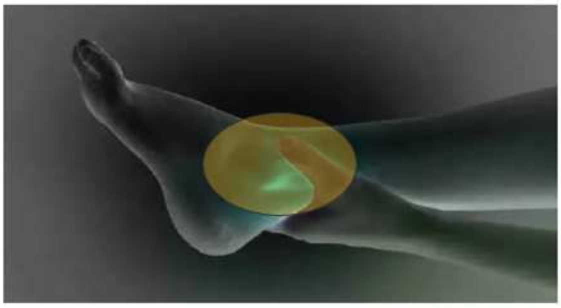

Figure 8 Diagram of the identification of the injury site

The physical exercise system identification is carried out through the intelligent algorithm of this paper. Figure 9 shows a schematic diagram of the recognition of exercise rehabilitation for lower limb injuries. It can be seen from Figure 9 that the intelligent system in this paper can effectively identify the injury points of the lower limbs, and recognize the human body sports training through the human bone joint points, and give targeted opinions.

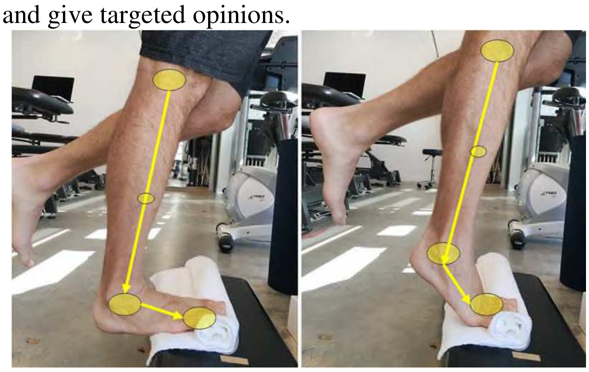

Figure 9 Schematic diagram of recognition of exercise rehabilitation of lower limb injury

Based on the above analysis, 72 groups of physical rehabilitation exercises are used to evaluate the system of this paper. The results are shown in Table 1.

Table 1 Evaluation of physical exercise rehabilitation system

Number	Physical exercise rehabilitation effect	Number	Physical exercise rehabilitation effect	Number	Physical exercise rehabilitation effect

1	89.9	25	93.9	49	82.2
2	93.4	26	85.1	50	87.6
3	83.7	27	90.7	51	88.6
4	82.3	28	91.1	52	87.4
5	82.5	29	87.7	53	93.1
6	85.7	30	93.8	54	90.7
7	82.8	31	91.2	55	89.8
8	82.3	32	84.8	56	86.8
9	91.6	33	87.2	57	85.7
10	85.1	34	87.8	58	87.0
11	84.7	35	82.1	59	82.2
12	89.4	36	88.9	60	92.0
13	93.0	37	91.9	61	86.1
14	90.2	38	93.2	62	87.2
15	87.0	39	85.1	63	86.9
16	92.5	40	84.0	64	87.4
17	91.2	41	85.8	65	87.1
18	90.2	42	87.6	66	90.3
19	85.2	43	93.6	67	90.7
20	94.0	44	88.2	68	87.3
21	88.7	45	93.9	69	90.2
22	91.6	46	85.0	70	84.1
23	89.2	47	89.5	71	88.5
24	82.4	48	87.7	72	90.7

It can be seen from Table 2 that the physical exercise rehabilitation system constructed in this paper has good results.

5. Conclusion

Gesture recognition and motion recognition algorithms are the most important interactive technologies in rehabilitation training. This paper combines the bone data obtained by Kinect to study the rehabilitation posture and motion recognition algorithm, and combines the multi-rule posture and motion algorithm with virtual reality technology to build a training system that integrates training and entertainment. Moreover, this paper proposes a posture recognition algorithm based on human vision, and defines the human posture described by the feature, and improves the classifier's ability to classify different posture data. The sensors on the fitness equipment are used to detect the user's exercise data and power generation, and the data is written into the NFC chip on the fitness equipment, and the data is read from the NFC chip through the mobile application APP with NFC function and uploaded to the cloud server. Finally, this paper combines experimental analysis to verify the effect of the method in this paper. From the research results, we can see that the method constructed in this paper has a good physical exercise rehabilitation effect.

I. Ethical approval
II. Funding details (In case of Funding)
III. Conflict of interest
IV. Informed Consent

Declarations

Research involving Human Participants and/or Animals: Not applicable
Conflicts of interest/Competing interests: Not applicable
Informed consent: Not applicable
Availability of data and material: Not applicable
Code availability: Not applicable
Authors' contributions: Nana Zhao - Data Collection, Supervision, Resources; Yinzhong Yan, Xiao Han - Analysis, Software, Manuscript- Initial editing; Gaofei Zhang, Long Chen - Concept and design, Results interpretation, ManuscriptFinal editing. Nana Zhao, Yinzhong Yan, Xiao Han, Gaofei Zhang, Long Chen have read and approved the manuscript.

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