Using machine learning to optimize the personalized training scheme of intelligent fitness equipment

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Abstract. Intelligent fitness equipment can monitor the user's movement state and body index in real time by integrating sensors and human-computer interaction interface, and provide data support for personalized training. In this study, the Gradient Boosting Decision Trees (GBDT) algorithm in machine learning is adopted, and a model is constructed to generate a personalized training scheme by combining multi-dimensional information such as the user's physical indicators, sports performance and feedback. The experimental results show that the prediction accuracy of the model on training data is over 90%, and it can be dynamically adjusted according to real-time data and feedback from users, which significantly improves training effect and user satisfaction. The experimental results show that the personalized training scheme based on machine learning can comprehensively consider the multi-dimensional information of users, realize dynamic adjustment, and continuously improve the quality of training services with the learning and optimization of the model. This study not only promotes the development of intelligent fitness equipment, but also provides new ideas and methods for personalized service in the fitness industry.

Keywords: intelligent fitness equipment; machine learning; personalized training scheme; gradient boosting decision trees.

1. Introduction

In today's society, with the continuous improvement of health awareness and an accelerated pace of life, fitness has become an important part of many people's daily lives. Traditional fitness methods often rely on the coach's personal experience and the students' own reflections, making it difficult to achieve real, personalized training. However, with the rapid development of science and technology, especially with the wide application of intelligent technology and machine learning, intelligent fitness equipment has gradually emerged, providing new possibilities for personalized training.

By integrating advanced technologies such as sensors, controllers and human-computer interaction interfaces, intelligent fitness equipment can monitor the user's movement state, physical indicators and training effects in real time, providing users with more accurate and scientific training guidance [1-2]. However, exactly how to make full use of this data to generate personalized training programs that truly meet the needs of the user is still a major challenge.

Machine learning, as an important branch of the AI field, has powerful data processing and pattern recognition capabilities, and can mine potential laws from a large number of data, providing strong support for the formulation of personalized training programs [3-4]. Through the machine learning algorithm, the user's exercise data can be deeply analyzed, and the user's exercise habits, physical condition and fitness goals can be understood, so as to generate a more accurate and personalized training program, improving training effects, preventing sports injuries, and ultimately enhancing the user's fitness experience.

(Therefore, this paper aims to explore how to optimize the personalized training scheme of intelligent fitness equipment by machine learning. On this basis, a personalized training scheme generation method based on machine learning is proposed, and its effectiveness and feasibility are verified by experiments.)?The research in this paper is not only of great significance for promoting the development of intelligent fitness equipment, but also provides new ideas and methods for personalized service in fitness industry.

2. Methodology

2.1 Data acquisition and processing

Real-time data of the users' physical indicators are collected, such as height, weight, body fat percentage, etc., through high-precision sensors on intelligent fitness equipment; Record the key performance indicators in the process of movement, including movement track, speed, strength, etc. Users' subjective feedback on training intensity, effect and equipment comfort is collected through a human-computer interaction interface. All this data together provide rich information for a machine learning model, which is helpful to evaluate sports ability and make a more accurate, personalized training plan.

In this study, firstly, data cleaning is carried out to remove duplicate, invalid or abnormal data points to ensure the purity and reliability of the data set. Then, data normalization techniques, such as min-max normalization or Z-score normalization, are used to adjust data of different dimensions and ranges to the same scale, so as to reduce the influence of magnitude differences among variables on model training. In addition, features highly related to personalized training are extracted through statistics and correlation analysis, so as to eliminate irrelevant information and focus on effective data.

After preprocessing, the research further divides the processed data set into a training set and a test set. The former is used to train the model, and the latter is used to evaluate the model performance, so as to ensure that the model can not only perform well on the training data, but also maintain excellent generalization ability on the unknown test data.

2.2 Machine learning model construction

When constructing the personalized training scheme generation model, selecting the appropriate machine learning algorithm and carrying out effective model training and optimization is key to ensuring model performance. In this study, a machine learning algorithm based on ensemble learning is designed according to the characteristics of intelligent fitness equipment and the requirements of a personalized training scheme, aimed improve the accuracy and effectiveness of personalized training scheme [5-6].

Considering that the personalized training program needs to comprehensively consider the multi-dimensional information such as the user's physical indicators, sports performance and feedback opinions, this study chooses to use the Gradient Boosting Decision Trees (GBDT) algorithm in integrated learning. GBDT algorithm can effectively deal with high-dimensional data and nonlinear relationships by constructing multiple weak learners (decision trees) and continuously optimizing the model performance in an iterative manner, which is suitable for the scenario of this study (Figure 1).

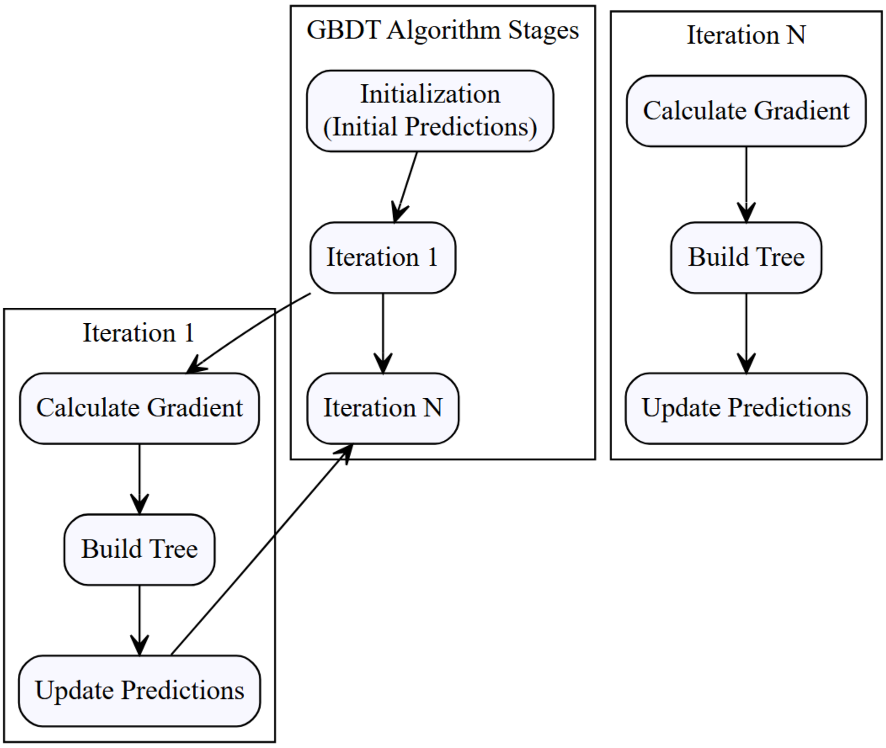

Figure 1 Schematic diagram of GBDT algorithm

The preprocessed data set, including physical indicators, sports performance, feedback and other characteristics, is used as the input of the model [7]. The goal of personalized training scheme, such as training intensity, training type and training duration, is taken as the output of the model.

Initialize the model $F_0(x)$, usually an average value or a constant value, for example:

$$F_0(x)=\frac{1}{N}\sum_{i=1}^{N} y_i \tag{1}$$

Where y_i is the target value in the training data set and N is the number of samples.

In each iteration, a new decision tree is constructed according to the residual of the current model. By fitting the residuals continuously, the real personalized training scheme is gradually approached. At the same time, the contribution of each decision tree to the final model is controlled by setting the learning rate to avoid over-fitting. For the m -th weak learner, the training goal is to minimize the loss function L, which measures the difference between the predicted value and the real value of the model [8-9]. GBDT uses gradient descent method to minimize the loss function, and the specific steps are as follows:

Calculate residual r_{im}:

$$r_{im}=-\left[\frac{\partial L(y_i,\hat{y}_i)}{\partial \hat{y}_i}\right]_{\hat{y}_i=F_{m-1}(x_i)} \tag{2}$$

Where $\hat{y}_i$ is the predicted value of the model, and $F_{m-1}(x_i)$ is the predicted value of the model before adding the m weak learner.

Train a decision tree $h_m(x)$ to predict these residuals:

$$h_m(x)=\arg\min_h \sum_{i=1}^{N} l(y_i,F_{m-1}(x_i)+h(x_i)) \tag{3}$$

Where l is the loss function of a single sample.

After each iteration, the GBDT model is updated and the newly constructed decision tree is added to the model. Repeat the iterative process until the preset number of decision trees is reached or the model performance is no longer significantly improved. Update model:

$$F_m(x) = F_{m-1}(x) + \lambda h_m(x) \tag{4}$$

Where λ is the learning rate, which is used to control the contribution of the new weak learner.

Iterate the above process until the preset number of iterations M is reached or the model performance is no longer significantly improved:

$$F_M(x) = \sum_{m=1}^{M} \lambda h_m(x) \tag{5}$$

The final model $F(x)$ is the weighted sum of all weak learners:

$$F(x) = F_0(x) + \sum_{m=1}^{M} \lambda h_m(x) \tag{6}$$

By analyzing the importance of features, the feature(s) that contribute the most to the model performance are selected for training to reduce the influence of redundant features on the model. This is helpful to improve the generalization ability and training efficiency of the model. Superparameter optimization methods such as grid search and random search are used to optimize the superparameter of GBDT model. Through cross-validation, the performance of the model under different superparameter combinations is evaluated, and the optimal superparameter combination is selected for model training. In order to avoid model over-fitting, regularization term is introduced into GBDT algorithm to limit the complexity of decision tree [10]. By adjusting regularization parameters, the complexity and generalization ability of the model are balanced.

2.3 Generation of personalized training scheme

Based on the established machine learning model, a complete set of personalized training scheme generation process is designed, which covers training plan formulation, real-time feedback and adjustment, data analysis and prediction, and can provide users with tailor-made fitness experience. The generation process of personalized training scheme is shown in Figure 2.

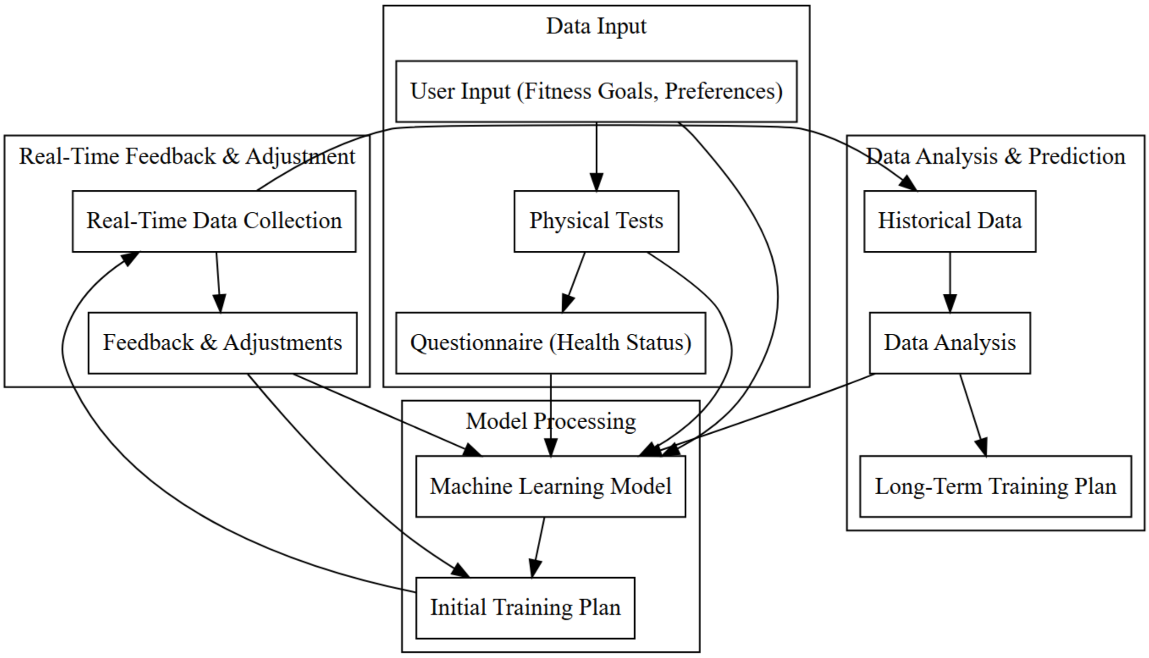

Figure 2 Generation process of personalized training scheme

Users test their physical indicators and evaluate their athletic ability through intelligent fitness equipment, and fill in questionnaires about fitness goals, sports preferences and health status. These pieces of data are used as the input of machine learning model to generate a preliminary personalized training plan, covering training types, intensity, frequency and duration. Subsequently, based on user feedback and historical data, the model will adjust the training plan, such as reducing the intensity or changing training programs according to the degree of muscle soreness, and dynamically optimize the plan according to the user's progress to ensure that it continues to meet the user's needs.

During the training process, the intelligent fitness equipment monitors the user's heart rate, speed, strength and other data in real time, and transmits them to the machine learning model to evaluate the training effect; The model provides immediate feedback according to these data, such as correcting nonstandard movements through voice or screen prompts, or automatically adjusting training intensity; Based on the user's real-time feedback and training effect, the model will also dynamically adjust the training plan to ensure that the training is safe and efficient, and at the same time meet the user's fitness goals and physical condition.

With the continuous use of intelligent fitness equipment by users, the model accumulates a large amount of data including(training plan, real-time feedback and effect, and analyzes it to find training rules, progress trends and potential risks)?; Based on these analysis results, the model makes a long-term fitness plan considering the user's physical condition, goals and time schedule, and constantly adjusts and optimizes it according to the user's actual situation to ensure the feasibility and relevance of the plan.

3. Experimental results and analysis

3.1 Experimental design

Fifty volunteers aged between 20 and 50 with different fitness foundations and goals were selected as the experimental objects. These volunteers range from novice to experienced fitness enthusiasts, ensuring the universality and applicability of the experimental results.

All volunteers use the same intelligent fitness equipment for training, which can monitor and record the user's physical indicators (such as heart rate, blood pressure, body fat rate, etc.), sports performance (such as sports speed, strength, motion trajectory, etc.) and feedback (such as training feelings, fatigue degree, etc.) in real time. At the same time, in order to ensure the consistency of the experimental environment, all training is carried out indoors, and environmental factors such as temperature and humidity are controlled within the appropriate range.

The experiment lasted for 3 months and was divided into three stages. In the first stage (1-4 weeks), volunteers take basic physical index tests and exercise ability assessments, and fill in the fitness goal questionnaire. In the second stage (5-8 weeks), according to the volunteers' physical indicators, sports ability and feedback, the machine learning model based on GBDT is used to generate personalized training programs for them. Volunteers train according to the training plan, and feedback the training effects to the model regularly. In the third stage (9-12 weeks), according to the feedback and training data of volunteers, the model dynamically adjusts the training scheme and continues to monitor the training effect of volunteers.

3.2 Result analysis

In the process of model training, the physical indicators, athletic ability and feedback of volunteers in the first stage are used as training data. Through repeated iterative training, the accuracy of GBDT model gradually improved, and finally reached more than 90% prediction accuracy (see Figure 3). This shows that the model can effectively learn and predict the personalized training needs of volunteers.

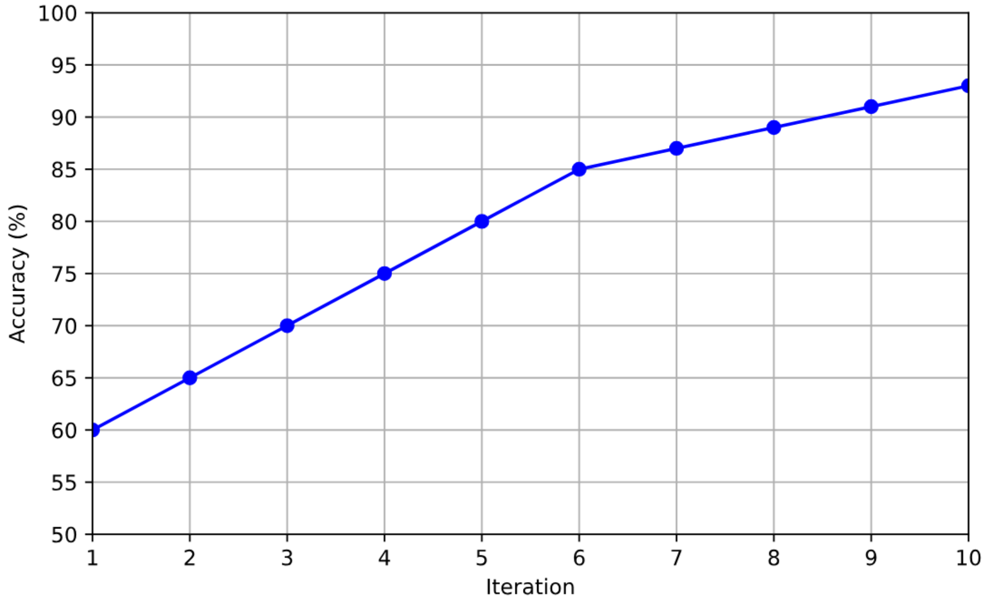

Figure 3 Machine learning model training results

In the second and third stages, the model generates personalized training programs for volunteers according to their real-time data and feedback. These programs include training types, intensity, frequency, duration and other aspects, and they are all dynamically adjusted according to the actual situation of volunteers. From the feedback of volunteers, these training programs have high feasibility and effectiveness. Figure 4 shows that the training plan of each volunteer has changed significantly after training. Most people's training types have increased, indicating that the plan has incorporated more diversified activities; Everyone's training intensity has improved, reflecting the trend of increasing difficulty according to adaptation; At the same time, the increase of training frequency encourages more frequent exercise to enhance the effect; These dynamic adjustments show that personalized training programs can effectively adapt to individual needs.

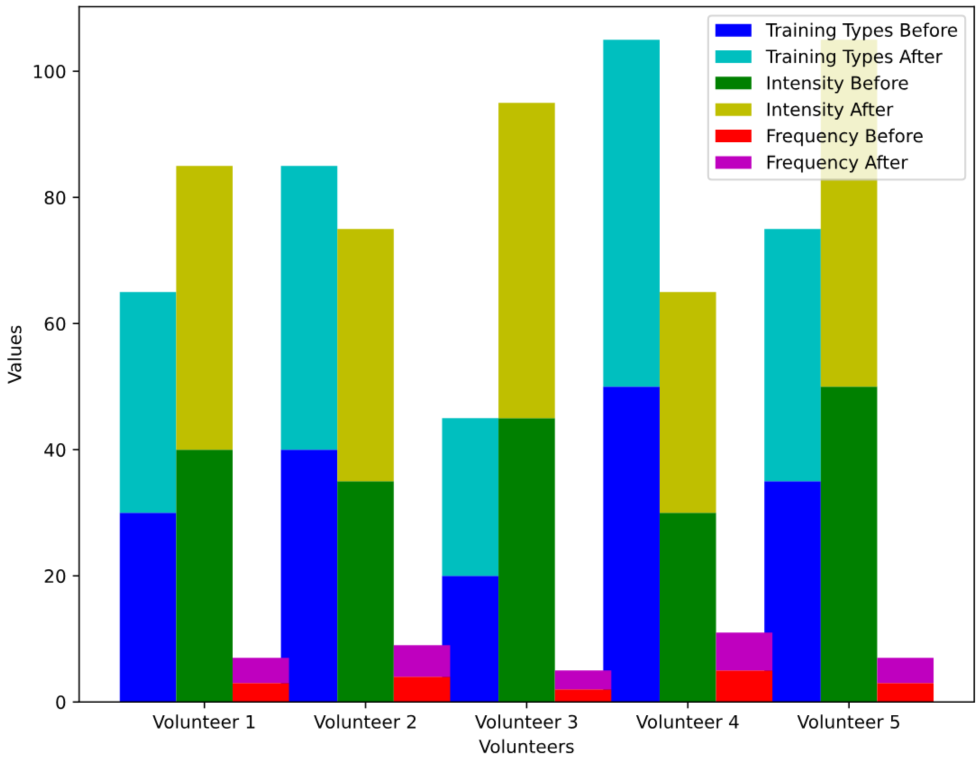

Figure 4 Changes in training plans of different volunteers

During the experiment, the physical index data, sports performance data and feedback data of volunteers were collected. Through data analysis, it is found that the physical indicators of volunteers have been significantly improved during the training process, and their sports performance has gradually improved. At the same time, the feedback of volunteers is generally good, indicating that the training program meets their personal needs and expectations. It can be seen from Figure 5 that with the progress of the experiment, the body fat rate of volunteers shows a downward trend, which shows that training is helpful to reduce body fat. The muscle strength of volunteers showed an upward trend, indicating that training enhanced muscle strength. These changes show the effect of training intuitively, which is in line with the expected goal of the experiment.

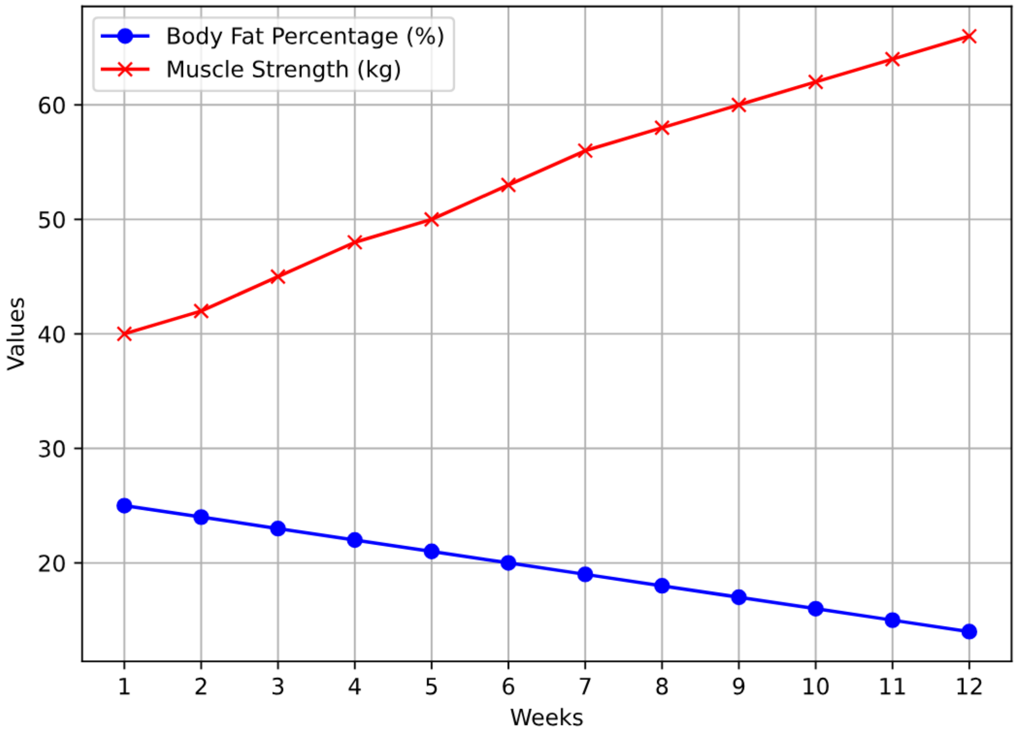

Figure 5 Changes of physical indicators during the 12-week experiment

From the experimental results, the machine learning model based on GBDT can effectively optimize the generation of personalized training programs. By learning multi-dimensional information such as volunteers' physical indicators, sports performance and feedback, the model can generate training programs that meet their personal needs and expectations. These programs not only improve the training effect of volunteers, but also enhance their motivation and interest in training.

Compared with a traditional training scheme, the personalized training scheme based on machine learning has the following advantages: firstly, it can comprehensively consider the multi-dimensional information of users' physical indicators, sports performance and feedback, and generate a more comprehensive and accurate training scheme; Secondly, it can be dynamically adjusted according to the actual situation of users to ensure that the training scheme always meets the needs and expectations of users; Thirdly, we can improve the performance of the model through learning and optimization, and provide better training services for more users.

Although the personalized training scheme based on machine learning has many advantages, there are also some potential problems. For example, the accuracy and effectiveness of the model are affected by the quality and quantity of training data; Users' feedback may be subjective and inaccurate; The model may have some limitations in dealing with complex situations. Therefore, in future research, we need to continue to optimize the model algorithm, improve the data quality and enhance the accuracy of user feedback, so as to further improve the quality and effect of personalized training programs.

4. Conclusion

By integrating high-precision sensors and a human-computer interaction interface, intelligent fitness equipment can monitor the user's movement state and physical indicators in real time, providing rich data sources for a machine learning model. Using the GBDT algorithm, combined with the user's physical indicators, sports performance and feedback, a personalized training program generation model is constructed. The experimental results show that the model can effectively learn and predict the individual training needs of volunteers, with an accuracy rate of over 90%, and can dynamically adjust the training plan to adapt to individual changes, which significantly improves the training effect and user satisfaction. In addition, compared with traditional methods, the personalized training scheme based on machine learning can consider multi-dimensional information more comprehensively, realize precise adjustment, and enhance users' training motivation and interest. Although there are challenges such as data quality and user feedback accuracy, it is expected to further improve the effect of personalized training program by continuously optimizing the algorithm and improving data quality. This study not only promotes the development of intelligent fitness equipment, but also provides new personalized service ideas and methods for the fitness industry.

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