Swimming Action Recognition and Analysis System Based on Intelligent Algorithm

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Abstract. With the development of science and technology, people's demand for swimming is gradually increasing. In order to meet people's needs, an intelligent swimming analysis system came into being. The intelligent swimming analysis system mainly uses smartphones as the main research platform, combined with wireless network technology, to identify and analyze human movements, provide relevant information, and then analyze the rationality of the movements. The article introduces three aspects: the design of swimming posture recognition and analysis system, swimming movement recognition algorithm and optimization algorithm, and the implementation of intelligent swimming analysis system. This article focuses on the design of the swimming posture recognition and analysis system, and provides a detailed description of the swimming posture recognition algorithm and optimization algorithm, finally, verifies the swimming action recognition algorithm and optimization algorithm through experiments. Experimental results show that the system designed in this article can effectively recognize and analyze swimming movements, and its recognition accuracy can reach up to 97.7%.

Keywords: Intelligent Algorithm, Swimming Action Recognition, BP Neural Network, Support Vector Machine, Genetic Algorithm

1. Introduction

With the development of technology, the emergence of smartphones allows people to enjoy various services anytime and anywhere. In recent years, smartphones have

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played an increasingly important role in our lives, playing an increasingly important role in our daily lives. The emergence of smart phones has greatly changed people's way of life. In life, we can use smartphones to obtain a lot of information. In swimming activities, people use smartphones to identify and analyze swimming postures, so as to facilitate their own swimming activities to master better movements.

In recent years, many outstanding scholars and experts have conducted research and discussions on swimming movements. Among them, Xiao Ju aimed at the key issue of swimming action recognition in the digital swimming monitoring system and proposed an independent swimming action recognition method based on the ideas of single attitude sensor and decision tree classification. The results show that this method can accurately identify the paddling and turning movements of four swimming styles, and the average recognition accuracy for training data and test data can reach 96.4% and 94.8% respectively [1]. Mei Jiwei discussed whether the basic technical movements of swimming meet the requirements of the learning and development guidelines for children aged 3-6 years. He found that preschool children learn to swim with basic physical fitness, and play a positive role in promoting the development of physical and mental health [2]. Qian Guangjian used the Gopro HERO 6 high-definition underwater 4K camera as the investigation equipment to film the movements of the athletes during swimming, and played the captured movements through computer equipment to comprehensively analyze the athletes. He explained the advantages and disadvantages shown in the movements, corrected the shortcomings, and used the training theory as a guide to further improve children's swimming skills [3]. The above literature is somewhat helpful for the optimization of swimming movements, but the details need to be strengthened.

Since there is currently very little research on movement gesture recognition and analysis, it is of great significance to conduct research in this area. Sports posture recognition and analysis refers to the use of smart phones to recognize people's sports postures and analyze their movements. The traditional method mainly uses cameras to capture human movements to complete action recognition and analysis. This method requires a lot of human resources and cannot meet people's growing needs well. The article uses smartphones as the main research platform and combines wireless network technology to complete motion posture recognition and analysis. This system can not only meet people's needs for swimming posture recognition and analysis, but also effectively reduce the consumption of human resources.

2. Design of Intelligent Swimming Analysis System

The intelligent swimming analysis system uses smartphones as the main research platform, combined with wireless network technology, provides relevant information by identifying and analyzing people's movement postures, and then analyzes the rationality of movements, thereby improving the accuracy of swimming postures. The intelligent swimming action analysis system mainly includes three aspects: first, identifying and analyzing the swimming movement posture; second, providing relevant information; third, conducting rationality analysis of the action [4].

First, the swimming postures must be identified to analyze the body postures and classify them according to different swimming movements, including freestyle,

breaststroke, butterfly, etc. Then analyzing the body posture, judge the rationality of each movement through intelligent algorithms, and make reasonable adjustments to different movements, so as to improve the level of swimming skills. Finally, relevant information is provided for users to use, including forward direction, backward direction and other information [5].

According to the above analysis, it can be seen that the intelligent swimming action analysis system mainly includes three aspects: the first is the smartphone platform; the second is swimming posture recognition; the third is the data transmission and management system. The smart phone platform mainly processes and analyzes the collected data. Firstly, the collected data is preprocessed and feature extracted. Preprocessing includes processes such as grayscale, binarization, and denoising. Feature extraction includes the feature extraction process of the human body motion posture signal in the video sequence, including the position information, speed information and motion posture information of each joint of the human body. After feature extraction is completed, intelligent algorithms can be used to determine the rationality of human movement postures. The obtained data is then processed and analyzed to obtain correct results and provided to users [6].

Swimming posture recognition refers to the recognition and classification of human movements in video sequences. In order to achieve this goal, it is first necessary to obtain raw data information and preprocess it to convert the raw video sequence into a digital image form. Then using digital image processing technology to denoise and smooth the video sequence to remove the possible noise interference in the video. Then, filtering, edge detection and other operations are performed on each frame of the video sequence to extract feature information of the video frame; and relevant algorithms are used to extract features of the processed video frames and identify human action postures; finally, classifying the video frames based on the human action posture results recognized by movement postures to determine whether the actions are reasonable [7].

Swimming posture recognition refers to the analysis and recognition of the position information, speed information and motion posture information of each joint of the human body. First, a template matching algorithm is used to classify swimming movements, when encountering movements that do not match the template matching, the interference signals can be removed through color coding, edge detection, smoothing, etc.; then using the three-value pattern algorithm and related algorithms to match the processed data samples with the template data samples; finally, the correct action sequence is obtained based on the matching results. After swimming posture recognition is completed, the action can be compared with the existing standard action to determine whether the action is reasonable, thereby improving the level of swimming skills [8].

3. Swimming Action Recognition Algorithm and Optimization Algorithm

The identification and analysis of swimming movements is mainly based on the actual situation, and provides some useful reference information for people by analyzing the posture changes of the human body during swimming. When identifying swimming

movements, the recognition is mainly performed by extracting the characteristic values of the human body. In order to improve the recognition rate, machine learning algorithms can be used to extract human body feature values and then identify swimming movements.

When performing optimization algorithms, different optimization objectives must be determined based on the actual situation. For different optimization goals, different algorithms need to be selected for processing. For the recognition of swimming movements, it is mainly to analyze the movement posture of the human body. In the action recognition, the BP (Back-propagation) neural network, support vector machine and other algorithms are used to analyze the human body movement posture.

When performing swimming action recognition, due to the certain complexity of swimming actions, it needs to be optimized. For BP neural network, the parameter values of the network need to be adjusted when recognizing swimming actions; for support vector machines, parameter values such as learning rate and learning rate need to be adjusted; while for the BP neural network, it is necessary to adjust the parameter values such as the threshold.

3.1 BP Neural Network

BP neural network is an important nonlinear mapping method, which can map a pattern in the input space to the output space, and its learning process can be expressed by formula (1) [9]:

$$Y = y(\sum_{i=1}^{n} kh - r) \tag{1}$$

In formula (1): Y is the total number of nodes in the input layer, y is the output layer nodes, k is the threshold during backpropagation, h is the dimension of the network training samples, and r is the error function.

For BP neural network, its main principle is to optimize the output vector by backpropagating the input vector. When optimizing the BP neural network, appropriate weight coefficients and thresholds should be selected according to the actual situation. For the weight coefficient, it should be determined according to the actual situation [10]. In the actual application process, the network parameters can be set as follows: the learning rate is 0.01, the number of hidden layer neurons is 10, the excitation function is the sigmoid function, and the threshold during backpropagation is 0.10. In the process of swimming action recognition, the network training samples can be divided into two parts: one part is training samples and the other part is testing samples.

3.2 Support Vector Machine

Support Vector Machine (SVM) is a new method based on statistical learning theory, which solves classification problems by establishing a linearly inseparable support vector machine model [11]. The expression function of the support vector machine is shown in formula (2):

$$w^T a + c = 0 \tag{2}$$

In formula (2), w represents the normal vector, and T represents the transpose. The

core idea of the support vector machine is to divide the data set into several non-intersecting subsets by constructing a hyperplane, so that the distance between different subsets is minimized, and the training samples and test samples overlap on this hyperplane. Classifying the training samples through the SVM classifier, and input the training samples into the SVM classifier for identification. If the classification error is minimum, the classification result can be determined [12]. In the process of swimming action recognition, the human body movement posture is mainly used as the input variable, and the human body characteristic value is extracted as the output variable, and then the two are trained and learned, and finally the recognition of the human body movement posture is realized.

3.3 Genetic Algorithm

Genetic algorithm is a random search algorithm that simulates the biological evolution process [13]. Its main expression is shown in formula (3):

$$k(a,b) = \tan(a) + \cot(b) + 0.1a + 0.1b \tag{3}$$

In formula (3), a and b represent the two main characteristics of the object. This algorithm can mutate by simulating the genes of organisms, encode functions as genes in calculations, encode them according to certain principles, and then perform corresponding fitness calculations. During the calculation process, fitness is used as the criterion for selecting individuals. If the fitness is higher than the optimal solution, the individual will be retained; if the fitness is lower than the optimal solution, it will be eliminated. Genetic algorithm mainly includes two basic operations: selection operation and mutation operation. In order to ensure the recognition rate, parameter values such as crossover probability and mutation probability can be used to optimize it [14].

4. Implementation of Intelligent Swimming Analysis System

The system mainly consists of smartphones, swimming analysis software, databases and wireless networks. The main functions of this system are [15]: (1) Action recognition. Users take photos in the swimming pool through the built-in camera of their smartphones. The system recognizes the photos as actions and compares them with the actions in the database to determine whether there are errors or unreasonableness. (2) Action analysis. During swimming, the user takes photos of various parts of the human body through the built-in camera of the smartphone, and the system uploads them to the database through the wireless network. The database mainly records the details of movements during swimming, such as the angle of a person's arm swing, the position of the palm, and other information, and analyzes whether the person's movements are reasonable. (3) Intelligent swimming analysis software. The user takes pictures of the human body through the built-in camera of the smart phone during swimming, and uploads the photos to the database. The system calculates the time stamp of each human body movement in the picture according to the time sequence and the size of the picture, and compares it with the data in the database. (4) Wireless network. Users can communicate with other users

through the built-in wireless network of smartphones to learn whether others have problems or unreasonable opinions about their actions.

In order to realize the above functions, we first need to build a swimming analysis model. The article uses people moving in the water as an example to establish a swimming analysis model. The movement of people in water is decomposed into multiple steps and corresponding to each step, and the analysis and recognition of human movements are realized through the swimming analysis model [16]. For example, in the process of swimming, people need to move left, right, forward, etc. According to the order of their movements, the swimming analysis model can be established as follows: first, human body motion is decomposed into multiple steps, and then these steps are mapped to each motion node, through corresponding motion feature extraction and algorithm recognition, it is converted into the corresponding action state and saved in the database, and finally judge whether there are unreasonable situations and make improvements based on different situations. The system optimizes system performance by continuously analyzing and identifying human body movements [17].

4.1 Feature Extraction

The premise of motion analysis of the human body is to obtain the characteristics of the human body at different stages, and the acquisition of motion characteristics is mainly completed by the recognition and extraction of moving targets. The article uses a method based on computer vision to analyze and identify people's movements in the water, which is mainly divided into the following two steps [18]:

(1) Image segmentation. Moving targets usually have complex shapes, so they need to be segmented. When segmenting, the first is to use the Hough transform method to detect the straight lines in the image, then use the LK optical flow method to extract the target trajectory, and finally use the Mean Shift algorithm to smooth the extracted trajectory.

(2) Feature extraction. After completing the segmentation of the moving target, feature extraction needs to be performed next. The article adopts the method based on video analysis to recognize and analyze the human action, and uses the motion feature extraction method to identify the human action. The article uses two main motion feature extraction methods: based on Hough transform method and based on optical flow method. The Hough transform method is a nonlinear transformation. Combining it with image segmentation can effectively extract moving targets, but it will consume a lot of calculation time during the calculation process, so the article uses the optical flow method. The optical flow method is a linear transformation, which treats each frame in the video stream as a pixel point, so as to obtain the contour trajectory of the moving target at different time intervals. The article uses the optical flow method to extract human motion features, and extracts each pixel in the video frame as a pixel for motion feature extraction. The swimming action data feature value extraction table is shown in Table 1.

Table 1. Swimming action data feature value extraction table

Eigenvalue extraction function definition	Acceleration		Angular velocity	
	j	Data	j	Data
A_j=mean(data)	1	X_{ang}	7	X_{acc}

	2	Y_{ang}	8	Y_{acc}
	3	Z_{ang}	9	Z_{acc}
	4	X_{ang}	10	X_{acc}
A_j=var(data)	5	Y_{ang}	11	Y_{acc}
	6	Z_{ang}	12	Z_{acc}

The feature extraction table is divided into 12 eigenvalues, including 4 for butterfly, 4 for breaststroke and 4 for freestyle. On this basis, the time stamps of the motion data and the motion markers in the real-time video are combined to form a motion dataset. A single swimming action data is divided into 36 fields: the first field is the action data number, the second field is the actual swimming action label, the third to 35th fields are the feature values of the action data, the 36th field is the time variable of the swimming action. Through the above two methods, the motion data under different swimming styles are processed respectively, and finally the corresponding motion parameter set is formed, including explanatory variables and target variables [19].

4.2 Feature Selection

Since there are certain differences between different motion modes, it is necessary to choose an appropriate feature to describe the corresponding motion mode. During swimming, the movement of the human body in the water is mainly completed by the upper and lower limbs. Therefore, when the human body moves in the water, it is mainly based on the upper limbs and lower limbs, and at the same time combined with the breathing method. For swimming action recognition, classification algorithms are usually used to classify it, such as naive Bayesian classifier, support vector machine, etc. Since each action has certain uniqueness, in the swimming analysis model, different feature extraction methods need to be selected for different movement modes. Commonly used feature extraction methods include: feature extraction based on feature selection algorithms. Feature selection is a method of selecting the most representative and relevant few categories from a high-dimensional data set as the classifier, instead of randomly using the entire data set as the input of the classifier. By choosing an appropriate feature extraction algorithm, the classifier can be made to better classify data in different categories.

Association rule algorithm is an algorithm that can discover potential connections and find new rules from them. The main idea is to discover the patterns hidden in the data set by analyzing and mining the connections, thereby establishing one or more rule bases with correlation (such as time, space, etc.) and causal relationships (such as influence, promotion, etc.) [20]. When the association rule algorithm processes high-dimensional data, it needs to establish a rule base with correlations such as causality and time order, and then input the rule base for processing.

The following factors need to be considered when selecting features: (1) extract representative features; (2) select the most representative and highly relevant features; (3) combine selected features and data sets to further improve classifier performance; (4) minimize the number of features; (5) find the most representative, highly correlated and most causal subset of features.

4.3 Action Recognition

Due to the complexity of video data, its analysis requires a lot of data acquisition and calculation. The article takes video data as an example. During motion recognition, the original data in the video must first be extracted, and then feature extraction

algorithms are used for data processing. The article uses a method based on principal component analysis to reduce the dimensionality of the original data and remove redundant information. Then using the K-means clustering algorithm to divide the human body into three groups, where the first group includes the human head and arms, the second group includes the human torso and legs, and the third group includes the human hands and feet. Finally, according to the extracted feature vectors of the three groups, the required feature vectors for each action in each group are calculated and stored in the database. Using principal component analysis to reduce the dimensionality of human actions can reduce the amount of data and increase the calculation speed. The first principal component is the principal component of the head and arms, and the second principal component is the principal component of the torso and legs. In the action recognition, the human body is divided into three groups by using the K-means clustering algorithm firstly, and then the human body action is recognized by the method based on principal component analysis.

4.4 Experimental Analysis

According to the above method, the swimming action classifier was constructed, and after optimizing it with the LOOCV method, the optimal classification recognizer for the four swimming strokes was obtained (positive example: turning action, negative example: stroke action), the corresponding minimum number of samples of leaf nodes are 89, 136, 380 and 423 respectively. For the learning data used to build the swimming action classifier, the classification accuracy was evaluated by precision, recall, and the comprehensive index F1 score.

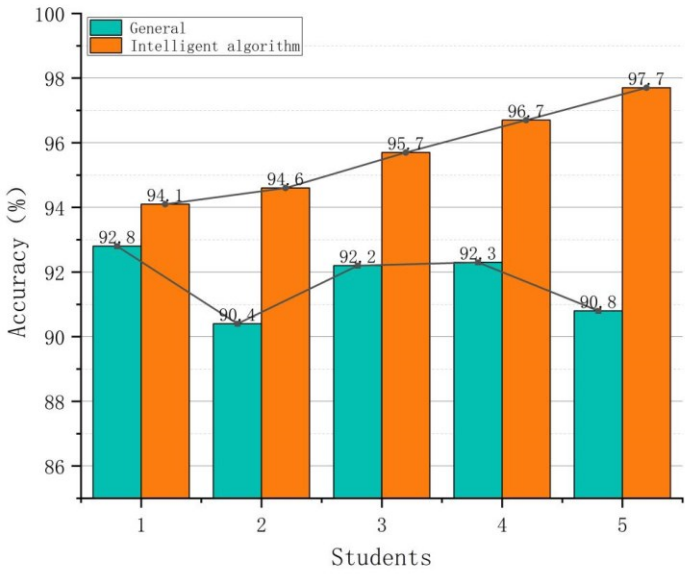

Fig.1 Recognition accuracy

As can be seen from Figure 1, the general recognition system has a highest recognition accuracy of 92.8% and a lowest accuracy of 90.4% for student swimming movements, and the calculated average accuracy rate is 91.7%; the recognition system based on intelligent algorithms has a highest accuracy rate of 97.7% and a lowest accuracy rate of 94.1%, and the calculated average accuracy rate is 95.76%. It can be seen that the swimming action recognition and analysis system based on intelligent algorithms is effective in improving recognition accuracy.

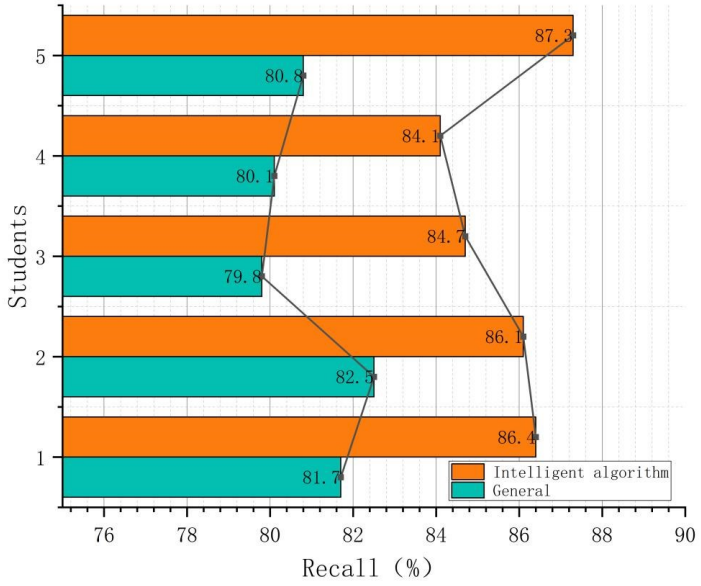

Fig.2 Recall rate

As can be seen from Figure 2, the recall rate of the general recognition system is as high as 82.5% and as low as 79.8%, the calculated average recall rate is 80.98%; the recall rate of the swimming action recognition and analysis system based on intelligent algorithms reached a maximum of 87.3% and a minimum of 94.1%, the calculated average recall rate is 85.72%. It can be concluded that the swimming action recognition and analysis system based on intelligent algorithms has a higher recall rate and can further improve the recognition and analysis results.

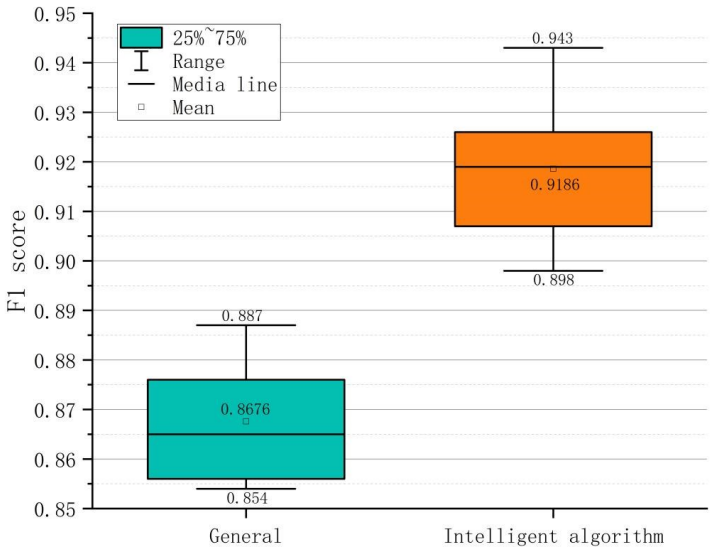

Fig.3 F1 score

As can be seen in Figure 3, the highest F1 score of the general recognition system is 0.887, the lowest is 0.854, and the calculated average score is 0.8676; the F1 score of the swimming action recognition and analysis system based on intelligent algorithms reached a maximum of 0.943, a minimum of 0.898, and the calculated average score was 0.9186. It can be seen that the F1 score of the swimming action recognition and analysis system based on intelligent algorithms has also been effectively improved.

5. Conclusions

The swimming posture recognition and analysis system is implemented on smartphones based on action recognition algorithms and wireless network technology. It can provide people with accurate and scientific swimming posture guidance through the analysis of swimming postures. At the same time, the system can also analyze and optimize human body movements based on action recognition algorithms, so as to better conduct swimming training and improve swimming training effects. With the improvement of people's living standards, people's demand for swimming has gradually increased, and at the same time, they have higher requirements for swimming action recognition. Therefore, the article designs an intelligent swimming action recognition and analysis system, which uses a mobile phone to identify human body movements, collects video information through the camera in the mobile phone,

and uploads it to the cloud server. The video information is analyzed and optimized through the cloud server, so as to get more accurate and scientific action guidance. The system has certain practicality and innovation.

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