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A Fast Tracking Method for Frontal Volleyball Spike Trajectory Based on Bee Algorithm

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ABSTRACT

This paper researches and designs a new method to assist volleyball players in better mastering skills. We first collected a color image, analyzed it, and applied histogram equalization for image enhancement. Ultimately, we successfully identified the image of a frontal spike using this method and employed the artificial bee colony algorithm to optimize its contour and trajectory, thus performing better in games. Through this experiment, we found that this method can effectively gather accurate frontal spike images, and by using histogram techniques, its signal-to-noise ratio was maximized. Simultaneously, it can capture the volleyball's edge contour, achieving a high tracking accuracy.

Keywords: Bee Algorithm,Forward and Backward Movement, Efficient Path Tracking, Smooth Line Distribution, Accurate Angle Check

1. Introduction

In volleyball matches, the correct movement path and technique can aid players in securing a victory. This movement path can help athletes predict opponents' counterattacks and provide references for decision-makers. Sports and behavioral analysis has long attracted numerous scholars, and its research value appeals to various disciplines, including psychology, biology, and computer science. From an engineering perspective, behavior recognition has extended to a broad range of high-impact social applications, including but not limited to intelligent video surveillance, video retrieval, and human-computer interaction, as mentioned earlier. Video-based behavior recognition has significantly contributed to the retail analysis, user interface design, robotic learning, medical diagnosis, and improving the quality of life for the elderly. As a result, an increasing number of researchers are dedicating themselves to the study of sports behavior recognition. The widely used motion features at present include trajectory, direction, speed, acceleration, and optical flow features.

Close observation of players' movement paths can help athletes understand their skills and provide valuable information for decision-makers. The Artificial Bee Colony (ABC) algorithm is a bionic intelligent computing method that simulates bee colonies seeking excellent honey sources. Although this algorithm has not yet become a new research hotspot, it has blossomed in the field of bionic intelligent algorithms. The ABC algorithm is a novel intelligent optimization method and has demonstrated performance superior to traditional algorithms like GA and PSO in many optimization problems. The ABC algorithm has shown its superiority in solving many optimization problems, but it has seldom been applied in research on tracking the trajectory of a frontal volleyball spike. The ABC algorithm has the advantages of fast convergence speed and potential parallelism. To apply it to the tracking of frontal volleyball spike trajectories, the algorithm's heuristic information, waggle dance, and foraging behavior need to be re-explained. In this paper, we have developed a new, efficient frontal volleyball spike trajectory tracking system using the bee algorithm, effectively improving the technical performance of volleyball and providing significant guidance for formulating its strategies and tactics.

2. Related Work

Researchers have invented a new method, that is, the human behavior recognition technique based on dense trajectories developed by StellMacher [2]. This technique effectively captures points of interest in video frames, constructing a highly accurate, reliable, repeatable, and predictable behavior pattern. This method can effectively capture points of interest in video frames, thereby constructing a highly accurate, repeatable behaviour pattern, enabling fast and accurate behaviour recognition. Chen [3] and other researchers have developed a novel multi-dimensional trajectory pooling three-dimensional convolution representation (MTC3D), which can effectively capture and process complex multi-scale information. Its results are highly accurate and stable and can also be combined with CNN's feature maps for more efficient simulation. Naveh [4] uses this new technology, i.e., third-order projection techniques, a series of iterative manipulations, and a temporal-based model, to greatly improve the system's efficiency. He used three different iterative manipulations and a series of iterative manipulations to achieve a system that accurately expresses human behavior. Nguyen [5] and others have developed a new prominent foreground trajectory extraction technique. By taking advantage of the low-rank matrix, it can effectively aggregate a large amount of related information and attribute the prominent subset to more important background information based on the importance of related information. Mangum W A used displacement sensing technology to determine the three-dimensional spatial position of moving objects and record their movement paths [6]. However, this technology has some shortcomings in dealing with various movement environments, such as the inability to accurately record the three-dimensional spatial position of moving objects and complex calculations. To solve this problem, Kandil [7] and other researchers proposed a new technique, i.e., using adaptive decay and oscillation to characterize the motion features of moving objects. By designing a Kalman filter, the frontal spike position of volleyball players can be better captured. However, this effect may produce negative results due to the low quality of the obtained images. To address this issue, this paper will focus on extracting the edge contour features from the front spike pictures of volleyball players and detecting angles during the process. Using the bee colony algorithm, we can accurately find the running path of the volleyball and use it for tracking. The trajectory describes the movement path of the target in space, so it becomes very easy to calculate the target's speed, direction, and other motion features. Mangum [8] and others, combining human spatial position, movement direction, and speed, proposed a three-dimensional (3D) scene trajectory clustering algorithm and proposed an indoor region of interest (ROI) extraction method. They also studied abnormal action sequences using the dynamic time warping (DTW) method. Tian et al. proposed a set of kinematic features to describe the velocity, acceleration, angular velocity, angular acceleration, kinetic energy, potential energy, and total energy of each human body joint [9]. Ahn H and others used kinematics to analyze similar motion patterns. They proposed a motion descriptor based on acceleration measurement data, skeletal joint features, and depth map information, demonstrating their potential for modelling motion dynamics [10].

3. Artificial Bee Colony Algorithm Based on Motion Trajectory

3.1. Standard artificial bee colony algorithm

In 2005, Finnish biologist Karaboga introduced the artificial bee colony (ABC) computation, a swarm intelligence algorithm based on honey-collecting behavior. It can effectively solve single or complex group optimization tasks [11,12]. Its characteristics include easy operation, small adjustment parameters, robust reliability, and high search capability, which has gained extensive research attention [10]. The ABC has been applied in many fields, including information mining, neural networks, and image information processing. However, ABC performs poorly in enhancing overall performance, especially in improving locality. To improve overall performance, many studies are devoted to enhancing the performance of ABC in this aspect. Figure 1 is the flowchart of the artificial bee colony algorithm.

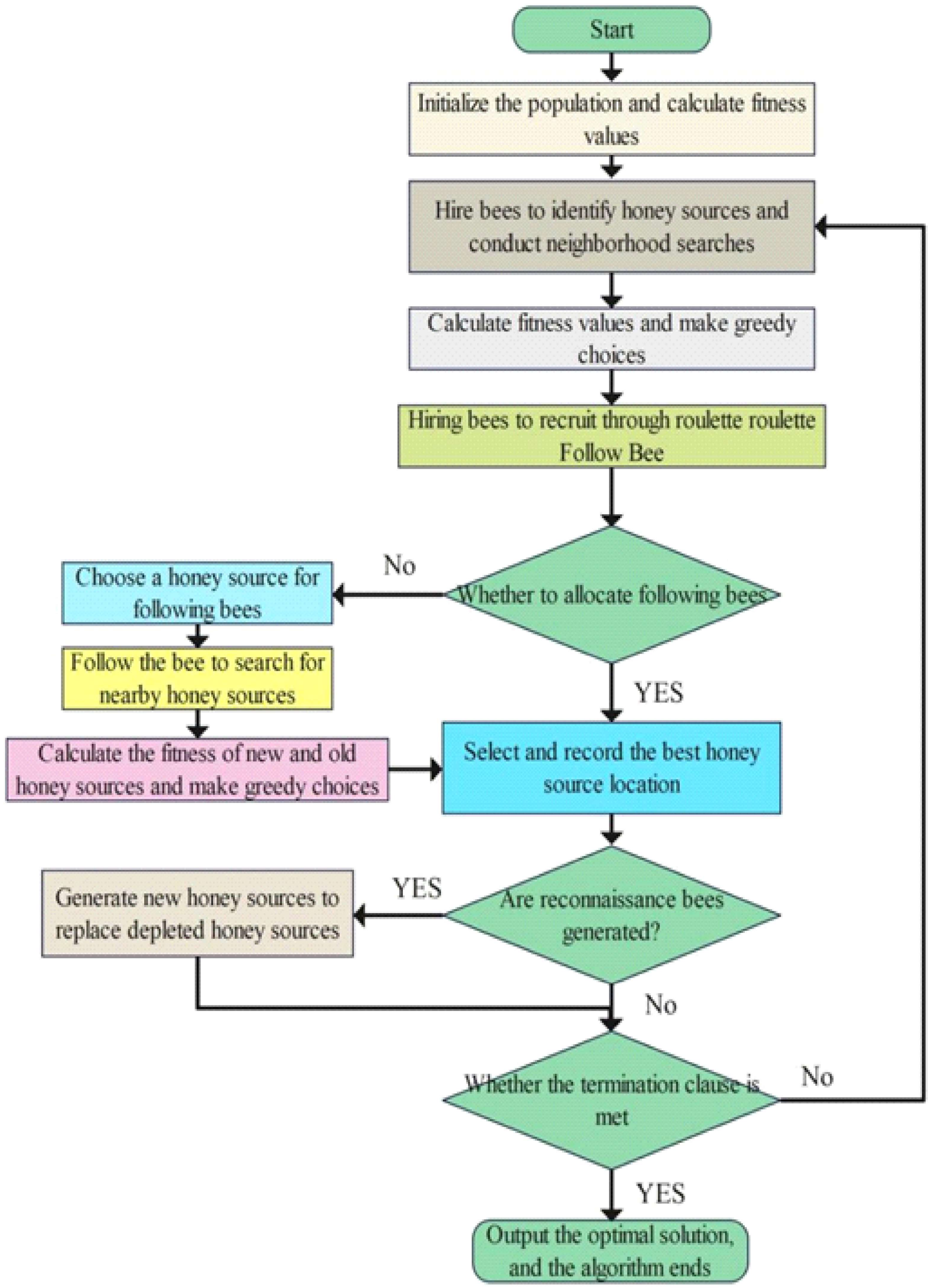

Figure 1. Flow Chart of Artificial Bee Colony Algorithm

The ABC algorithm divides the bees into employers, onlookers, and scouts. Each group consists of half of the colony. Onlookers are primarily used for information gathering, while onlookers will track the scouts to their destination [13-15]. Once the destination has disappeared, the scouts will immediately go to the location to gather more information. The ABC algorithm starts the search from SN uniformly distributed honey sources in the form of *xi* (i= 1,2, ..., SN) to determine an effective optimization solution and determine the dimensions of this solution in the form of D. The algorithm typically consists of three steps: employment, onlooker, and scout, to choose the best results of this solution.

1) During this period, we must explore and mine honey sources according to some formulas, discover new honey sources and then use a greedy algorithm to derive the best results.

$$v_{ij} = x_{ij} + \varphi_{ij} \left(x_{ij} - x_{kj} \right) \tag{1}$$

vij represents *v*, a new honey source searched nearby xi, and k is a randomly generated value [-1,1], its range is 1, 2, ∈, D, and φij.

2) Using the roulette wheel selection, we can decide whether to look for a new honey source based on the observed fitness. This step may be more effective than traditional methods. We will use the roulette wheel selection to determine which honey sources are suitable for our needs, and this step will be the same as traditional methods.

3) If a honey source's update times have not reached the preset limit after several iterations, it needs to be discarded and entered into the scout phase. In this phase, the scout bees will randomly use formula (2) to seek new solutions, replacing the existing ones.

$$x_{ij} = x_{\min j} + rand[0,1]\left(x_{\max j} - x_{\min j} \right) \tag{2}$$

Min *j* and max *j* represent the lowest and highest points of the j^{th} dimension, respectively, with a wide range of values.

3.2. Volleyball Spike Trajectory Tracking Based on Artificial Bee Colony Algorithm

To effectively track a volleyball's correct flight path, we must first create a model to collect relevant data. This model can be used to capture the details in each frame, including the volleyball's shape, location, and other features. We can accurately track the ball in each frame through these steps, ultimately achieving the desired result.

Firstly, by using the variational method and the Euler-Lagrange equation, we can transform the low-dimensional image space into a high-dimensional space, thus constructing a three-dimensional volleyball spike image model to better capture and analyze the details in the image [16,17]. By histogram equalization, we can significantly enhance the edge contour information of the collected volleyball spike image, thereby more accurately capturing the contour of the motion. This process includes two steps: 1) converting the image into a grayscale image to better capture the motion's details.2) Enhancing the histogram of the grayscale image of the volleyball spike. Through histogram equalization, we can effectively suppress the noise in the original spike image, enhance the image's contrast, and ensure the completeness and accuracy of the spike action, making the edge contour of the spike action clearer and more recognizable.

With the established volleyball spike image data collection model, we can extract relevant boundary lines from it and use specific markers for the overall analysis, forming an accurate, reliable, visual, and identifiable volleyball boundary line. By analyzing the side face and head features of volleyball athletes, we can extract a similar closed interval from their side face and head features and thenImprove the ambiguity of this interval by loading information from adjacent frames, effectively tracking their side face and head features. By adopting artificial intelligence algorithms, we can effectively improve the movement contour and angle of the volleyball so that it can accurately track the spike trajectory in front. Firstly, please select one from the volleyball edge contour pictures in adjacent frames and perform an angle analysis to calculate its corresponding angle value. Secondly, the calculated angle value is used to set the bee colony algorithm's initial density to calculate the volleyball's corresponding angle motion trajectory when spiked. Third step: according to their adaptability, divide the bees into two types: one is bees that specialize in collecting nectar, and the other is followers. Fourth step: by applying formula (3), we can help bees find more honey sources, and by observing the change in the corner points of the volleyball edge contour during a spike, we can infer their changing trend to obtain more information.

$$V_i^j = \left(1+\varphi_i^j\right) X_i^j - \varphi_i^j X_k^j \tag{3}$$

In this formula, j ∈ { 1,2, ..., D} refers to the change in the corner of the volleyball's edge contour; k ∈ { 1,2, ..., N.} refers to the same position following the volleyball, and Ne refers to the same position following the volleyball, while the changes in k and j can be random; φ*ij* ranges from -1 to 1, and *Xjk* refers to the adaptability at the same following position.

Step Five: According to the selection probability of each tracking volleyball's contour corner point, calculate the position of that corner point to determine the way of nectar collection. Suppose the probability value is proportional to the adaptability of the honey source. In that case, we can let the volleyball tracking continue to search around this honey source until it reaches the best adaptability. At this point, they can be upgraded to nectar-collecting bees. Use formula (4) to estimate the selection possibility of the volleyball contour corner point's position that is:

$$T_s = f\left(X_i\right) \sum_{m=1}^{N_e} f\left(X_m\right) - 1 \tag{4}$$

In this equation, *Xi* represents the position of the corner point, *Xm* represents the total number of corner points rotating during the volleyball's movement, and f refers to the improved bee colony.

In the sixth step, if a corner that meets the requirements is still not found after multiple rounds of search, stop the search, indicating that all possible positions in volleyball movement have been found. Based on the positions that have been found, we can calculate the volleyball's normal movement trajectory, thereby completing the final tracking.

4. Experiment Design and Analysis

4.1. Experiment Design

By using the MAT-LAB software, we collected 3000 front attack videos of volleyball athletes in a university gym. These videos were shot with a G·V16 camera, which was 2.4 m apart and could capture 80 frames per second. We can use these videos for analysis and comparison and use the algorithm in MATLAB to predict and track the front attack trajectory of these athletes. The trajectory tracking capability of the method we propose is evaluated through practical application.

4.2. Analysis of Experimental Results

We used a new technique to collect images of volleyball front attack frames and compared them with existing studies [5] and [6]. We found that this technique could effectively improve the quality and accuracy of the frames. We also studied the signal-to-noise ratio of the frames using this technique at different times to evaluate its performance. According to Figure 2, our experiments produced satisfactory results.

According to the data in Figure 2, the signal-to-noise ratio of the volleyball frame images processed by the three different techniques is gradually improving. Our research found that the signal-to-noise ratio of volleyball frame images processed using our technique is the highest, reaching up to 31.5 dB. In contrast, the technique proposed in the literature [5] we used has the worst signal-to-noise ratio. After testing, we found that the front attack images generated using this method are of excellent quality and have a significant visual impact.

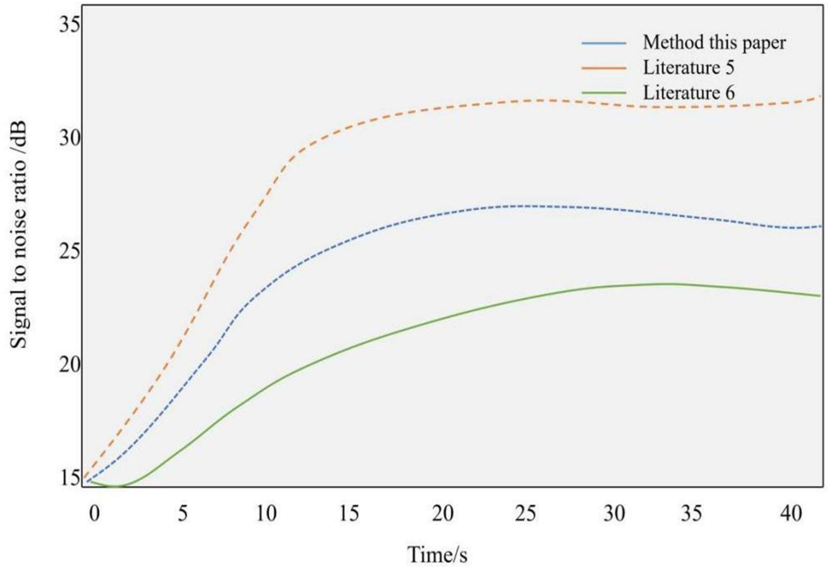

Figure 2. Analysis of Signal-to-Noise Ratio for Front Attack Images

Through the method proposed in this paper, we can effectively track the trajectory of the volleyball front attack. Compared with the research results in the literature [5] and [6], our experimental results are more accurate, as shown in Figure 3.

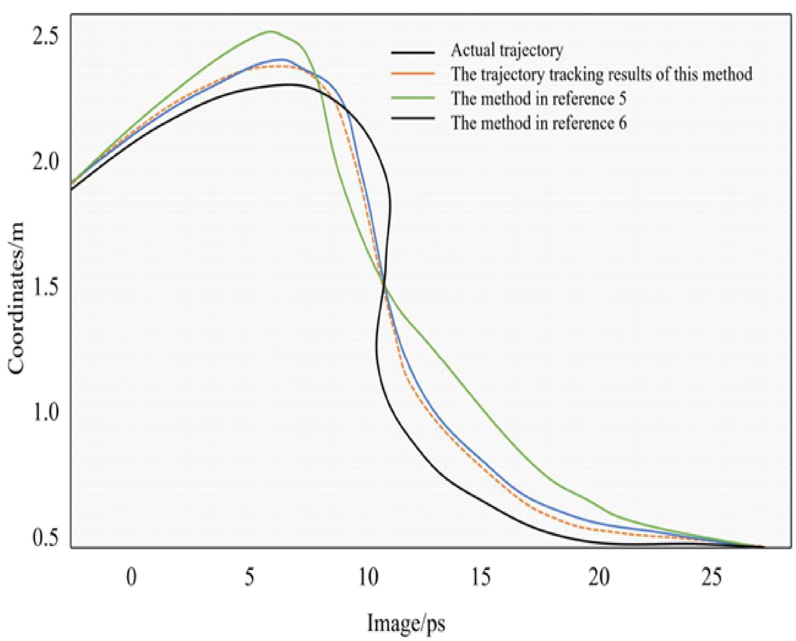

Figure 3. Results of Tracking the Trajectory of Front Attack in Volleyball

By observing Figure 3, we find that the trajectory of the front attack tracked by our method conforms to the actual situation, and the slight difference between the two trajectories is almost negligible.

5. Conclusions

Using the swarm algorithm, we can effectively track the correct position of the volleyball. This algorithm can help us understand the skills and strategies of volleyball players and assist us in formulating targeted defensive strategies. In this research, we found that the swarm algorithm can effectively improve the quality and accuracy of volleyball, enabling us to capture the players' skills and strategies accurately. Additionally, the swarm algorithm can effectively capture the outline of the players' bodies and heads, thus helping us understand their skills and strategies. After precise tracking, we found a perfect front attack path with very low error.

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