Retraction Notice

The Editor-in-Chief and the publisher have retracted this article, which was submitted as part of a guest-edited special section. An investigation uncovered evidence of systematic manipulation of the publication process, including compromised peer review. The Editor and publisher no longer have confidence in the results and conclusions of the article.

QJ, YW, and PG either did not respond directly or could not be reached.

Detection and tracking of moving targets in martial arts sports arena video based on non-scene target features

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Abstract. With the vigorous development of contemporary information technology, the field of computer technology is constantly innovating and progressing. Among them, the field of computer vision has achieved more prominent development. Computer vision is a discipline that uses cameras and computers to imitate the structure of human organs, processes and analyzes the collected video sequences, and then makes corresponding behavior judgments. Moving object detection and tracking is an important branch of computer vision. Moving target detection and tracking has broad application space and development scenarios. Here, we aim to study the detection and tracking method of moving targets in a martial arts arena video based on non-scene target features. Based on this research theme, we combine the particle filter moving target tracking algorithm based on non-scene target features to carry out the moving target detection and tracking experiments in the video of the martial arts arena. The experiment concluded: compared with the conventional methods, the particle filter moving target tracking algorithm based on the non-scene target features can perform the following tasks without affecting the detection accuracy. It reduces the time for detecting and tracking the same moving target in the video of the martial arts arena by 1.5 min. It shows that the algorithm can improve the efficiency of non-scene moving target detection and tracking. © *2022 SPIE and IS&T* [DOI: 10.1117/1.JEI.32.1.011206]

Keywords: non-scene target features; martial arts arena video; moving target; detection and tracking.

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1 Introduction

In recent years, with the continuous innovation and development of science and technology, the field of computer vision has also achieved remarkable development, including the progress of moving object detection and tracking methods. Moving object detection and tracking refers to extracting the required moving parts from the background scene by analyzing and processing continuous video images, then locating and locking the extracted moving target using a rectangular frame. Over time, the frame changes in size, position, and shape as the target moves. Connecting the frames in all video sequences that have changed can form a certain trajectory, i.e., a moving target tracking trajectory. According to the obtained moving target tracking trajectory, the movement changes of the moving target in the background scene can be clearly seen. Therefore, it can be concluded that the moving object detection and tracking technology is a technology that can clearly display the motion change trajectory generated by the moving object in the background scene. In the contemporary society with the rapid development of science and technology and network technology, moving target detection and tracking technology has a broad development prospect, and has also been more widely used in various fields. The applications of moving target detection and tracking technology include intelligent transportation, human–computer interaction, intelligent medical care, and military and national defense. In general, moving object detection and tracking refers to moving object detection and tracking in a specific scene. The detection and tracking of non-scene target features refers to the detection and tracking of moving objects in non-specific scenes, e.g., moving target detection and tracking in videos of various sports events. This paper studies the detection and tracking of moving objects

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in martial arts arena videos in non-scene target features. To sum up, moving target detection and tracking technology has a wide range of applications, involving all aspects of people's lives. Therefore, the research on moving target detection and tracking technology has certain practical significance and social value.

The innovation of this study is that:

1. Based on the characteristics of non-scene targets, the research on the detection and tracking methods of moving targets in the video of martial arts arena, which is relatively rare in the academic world, is carried out.
2. Combined with the conventional moving target detection and tracking method and the particle filter moving target tracking algorithm with non-scene target features, the moving target detection and tracking experiments in the video of the martial arts arena are carried out, and effective conclusions are drawn.

2 Related Work

Since the research on moving target detection and tracking technology has high practical research significance, there are many kinds of research related to moving target detection and tracking technology in academia. Among them is Jemilda's and Baulkani's research that uses genetic clustering algorithm to explore the range of motion kernel fuzzy mean value in moving target detection and tracking technology. A moving target kernel fuzzy *c*-means algorithm based on genetic clustering algorithm for cluster analysis of moving target trajectory is proposed.[1] Yazdi's and Bouwmans's research mainly introduces the latest methods for detection and tracking of moving objects in video sequences captured by moving cameras. The challenges and main concerns in the field of moving object detection and tracking technology are presented, as well as some benchmark databases that can be used to evaluate the performance of different moving object detection and tracking algorithms.[2] Through his research, Alessandro and Stefano proposed a system for the exposure of moving objects' motion trajectories that combines several commonly used moving object detection and tracking methods. The system can obtain better detection and tracking effect of moving objects in various scenes by intelligently arranging several commonly used moving object detection and tracking methods and adjusting the dynamic threshold of moving objects.[3] An et al. proposed a new framework for moving object detection and subsequent tracking using a four-layer low-end 3D scanner. This framework obtains a robust association between detection and tracking by detecting the moving contours of target objects.[4] Mahalingam and Subramoniam proposed in their research that ensuring the accuracy of moving target detection and tracking in complex scenes is a major problem for moving target detection and tracking. Then, he proposed a video sequence with powerful object detection and tracking capabilities. And through experimental analysis, it is proved that the video sequence can effectively improve the accuracy of moving target detection and tracking in complex scenes.[5] The research of Murugan et al. found that the video surveillance system plays an important role in the detection and tracking of moving objects, and proposed a more effective surveillance system deployment method in a wide range of applications.[6] Although the studies are closely related to moving target detection, these studies are relatively complicated and take a long time.

3 Way for Detecting and Tracking Moving Objects in Martial Arts Arena Videos

3.1 *Overview of Moving Object Detection and Tracking*

Moving object detection and tracking is a classic topic in computer vision research. It can provide important information, such as the size, position, speed, and trajectory of moving objects. The basic task of moving object detection and tracking can be briefly described as determining or estimating the effective position, velocity, and trajectory of moving objects of interest in video sequences.[7] The objects of moving target detection and tracking are generally people or general things. Common moving target detection and tracking methods include frame difference method, background difference method, Gaussian mixture model, tracking algorithm based on target modeling and positioning, and tracking algorithm based on filtering and data association. Among them, the tracking framework based on target modeling and localization generally obtains the target information to be detected and tracked through manual interaction or automatic target detection. The mathematical model of the target object is established, and then the tracking task of the moving target is realized by the window centroid matching tracking method. The tracking algorithm based on filtering and data association generally establishes the motion equation of the target according to the actual situation. Among them, the tracking framework based on target modeling and positioning generally first obtains the target information to be detected and tracked through manual interaction or automatic target detection means, and establishes a mathematical model for the target object, and then completes the detection and tracking task of the moving target. It realizes the prediction of the real-time motion trajectory of the target, and then realizes the extraction of the real target motion trajectory through appropriate filtering or data association algorithms.[8] The technical composition of moving target detection and tracking can be shown in Fig. 1.

However, although these technologies and methods mentioned provide many convenient conditions for moving target detection and tracking. However, there are still some problems and challenges in the process of moving target detection and tracking. The first is the change of lighting in the real scene: any changes in light intensity due to weather changes or other factors such as human factors may lead to changes in background pixels, thereby, affecting the accuracy of target detection and tracking.[9] The second is the interference of the dynamic background: some dynamic backgrounds, such as the breeze swaying the water, the breeze swaying the leaves, etc., may be misjudged as foreground pixels. As a result, a large number of highly disturbing noise points are caused, which affects the target detection. Next is the state change of the moving target or background, e.g., an object in motion suddenly stops, or an object in the background that is in a static state suddenly starts to move, etc. The state change of these objects and the resulting background update will also have a certain impact on the detection and tracking of moving objects. There is also the existence of the target shadow: a moving object may produce shadows under the projection of light, and as the moving object moves, its shadows will also change accordingly. In moving target detection, the shadow of the target object is often mistakenly used as part of the detection and tracking target, thereby, reducing the accuracy of moving target detection and tracking. The last is the case where the moving target is similar to the background image: when the moving object is similar to the background image, it is very easy to hinder the extraction of the current moving object, thereby, greatly reducing the detection and tracking accuracy.[10] To sum up, it can be seen that in the process of moving target detection and tracking, although there are many effective methods and technologies to help it, there are inevitably problems encountered in the process of detection and tracking. The process of moving target detection and tracking is shown in Fig. 2.

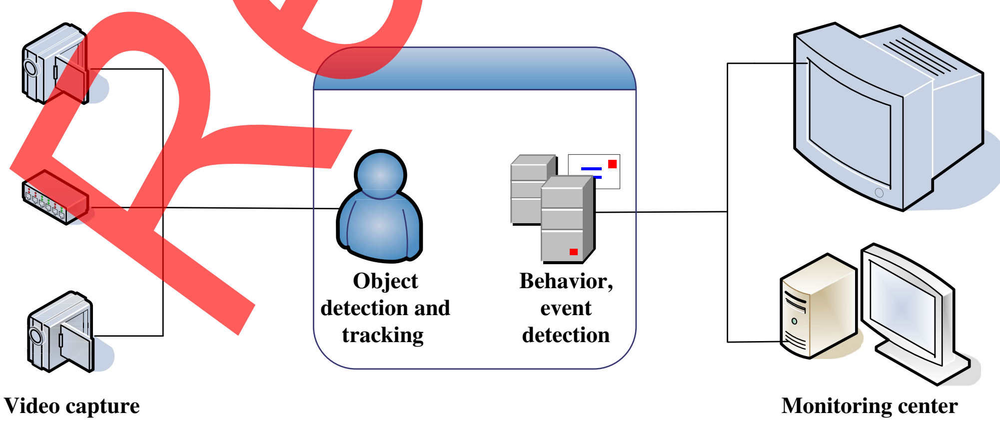

Fig. 1 Composition of moving target detection and tracking technology.

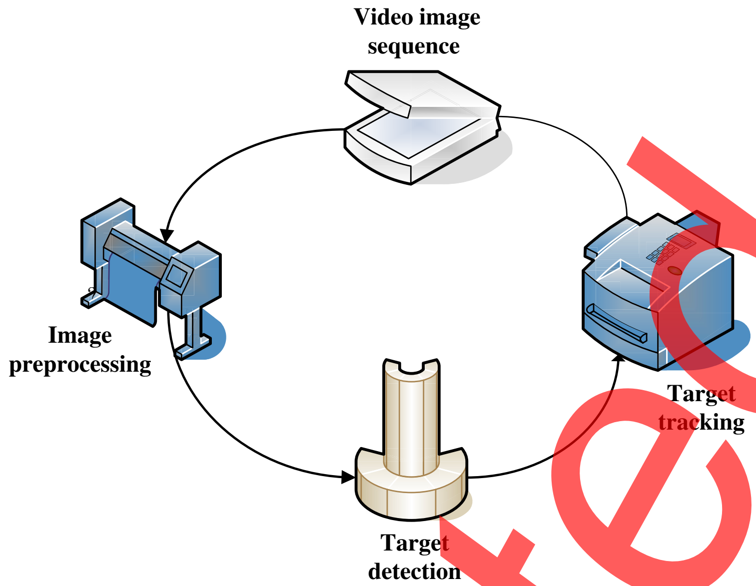

Fig. 2 Flow chart of moving target detection and tracking.

3.2 *Particle Filter Moving Target Tracking Algorithm Based on Non-Scene Target Features*

The basic idea of particle filtering is to give different weights to some sampled particles to form a particle set, then approximate the probability density distribution of the target state of the system, and then predict the trajectory of the moving target. Particle filter is also known as sequential Monte Carlo method. The basic idea is to approximate the posterior probability density distribution of the target state of the system by giving some discrete random sampling particles different weights to form a particle set. The particle filter moving target tracking algorithm based on non-scene target features can handle nonlinear and non-Gaussian situations simply and flexibly, and has a good anti-noise ability, is one of the commonly used moving target detection and tracking algorithms.[11] Its principle is essentially based on Bayesian probability, which regards unknown parameters as random variables, and uses a priori and currently detected information as input to predict the state of the unknown system.[12] This principle can be shown in Fig. 3.

The dynamic space model of the general particle filter moving target tracking algorithm includes the state transition model and the observation model.

Transfer model:

$$x_a = f_a(x_{a-1}, v_{a-1}). \tag{1}$$

Observation model:

$$y_a = h_a(x_{a,} u_a). \tag{2}$$

Among them, x_a and y_a are the system state and observation value, respectively. Both f_a and h_a are nonlinear functions. v_{a-1} is the system input information. u_a is the system measurement noise, and these elements are independent and identically distributed.[13]

According to the Bayesian estimation theory, the whole process includes a prediction stage and an update stage, which are executed alternately.[14] Assuming that the initial probability density function of the known system state is $p(x_0/z_0) = p(x_0)$, the posterior probability density function of predicting the current K moment can be deduced as $p(x_a/z_{1:a})$ as

$$P(x_a/z_{1:a-1}) = \int p(x_a, x_{a-1}/z_{1:k-1}). \tag{3}$$

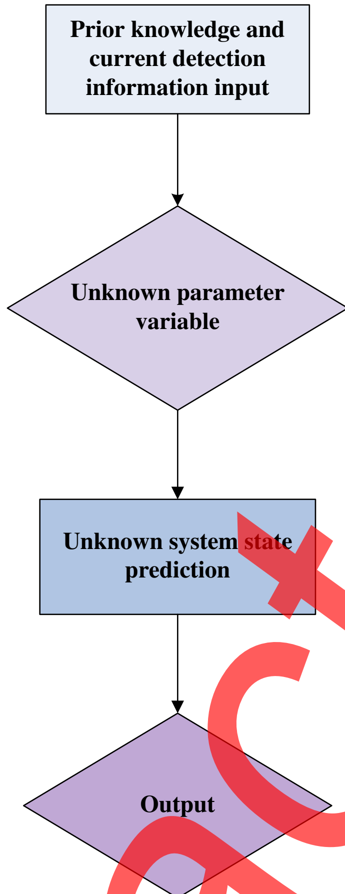

Fig. 3 Principle of particle filter moving target tracking algorithm.

State prediction:

$$P(x_a/z_{1:a-1}) = \int p(x_a/x_{a-1})p(x_{a-1}/z_{a-1}). \tag{4}$$

Status update:

$$P(x_a, z_a) = \frac{p(z_a/x_a)p(x_a/z_{a-1})}{p(z_a/z_{1:a-1})}. \tag{5}$$

Among them, $p(x_a/z_{1:a-1})$ is a normalized constant, and $P(x_a, z_a)$ is the updated target motion state:

$$p(z_a/z_{1:a-1}) = \int p(z_a/x_a)P(x_a/z_{1:a-1}). \tag{6}$$

Substituting it into Eq. (5) to get:

$$p\left(\frac{x_a}{z_{1:a}}\right) = z\frac{p(z_a/x_a)}{\int p(x_a/z_{1:a-1})}. \tag{7}$$

One of the important steps in the particle filter moving target tracking algorithm is sequential importance sampling. That is, in practical applications, the recursive method is used to calculate the particle weights. After the calculation, the posterior probability density function $q(x_{0:a}/z_{1:a})$ is estimated again. This step can effectively solve the problem of large amount of computation and poor real-time performance.[15] The specific recursion method is as follows:

$$q(x_{0:a}/z_{1:a}) = q(x_{0:a-1}/z_{1:k-1})q\left(\frac{x_a}{x_{0:a-1}}, z_{1:a}\right), \tag{8}$$

which is

$$q(x_{0:a}/z_{1:a}) = \prod_{a=0}^{a} q(x_a/x_{a-1}, z_a). \tag{9}$$

Under certain conditions, if the observed data obtained each time are independent of each other, and the value of the new state in the importance sampling function is only related to the previous state value,[16] then

$$p(x_{0:a}) = p(x_0)p(x_i/x_0), \tag{10}$$

which is

$$p(x_{0:a}) = \prod_{b=1}^{a} p\left(\frac{x_b}{x_{b-1}}\right). \tag{11}$$

The main process of sequential importance sampling is as follows:

First, randomly sample N samples $x^b_{o:a}) \sim q(x_a/x^b_{0:a-1}, z_{1:a})$, according to the importance probability density function, and then using the latest measurement value to obtain the importance weight of each particle as[17]

$$\omega_a(x^b_{0:a}) = \omega\frac{p(z_a/x^b_a)(x_a/x^b_{a-1})}{q(x_a/z_{a-1})}. \tag{12}$$

Then normalizing the weights corresponding to each particle as

$$\omega_a = (x^b_{0;a-1})\sum_{b=1}^{N}\omega_a. \tag{13}$$

Finally, the posterior probability density $p(x_{0:a}/z_{1:a})$ of the state is estimated, which can be approximately expressed as

$$p(x_{0:a}/z_{1:a}) \approx \sum_{b=1}^{N}\omega_a(x^b_{0:a})\delta(x_a - x^b_a). \tag{14}$$

The specific steps of the particle filter algorithm are as follows:

1. Initialization: $a = 0$, from the prior probability distribution $p(x_a)$, randomly sampling N particle sets $\{x^b_{0:a}N$.
2. Non-scene targets, the research calculation of importance weights. Setting $a := a + 1$, sampling $x^b_a \sim q(x_a/z_a)$ to get the particle set $(x^b_{0:a})$ at time a.

Importance weight calculation:

$$\omega^b_a = \omega_{a-1}\frac{p(z_{a/}x_b)p(x_{a/}x_{a-1})}{q(x_a/z_a)}. \tag{15}$$

Normalize the weights:

$$\omega_a = \frac{\omega^b_a}{\sum_{b=1}^{N}\omega^a}. \tag{16}$$

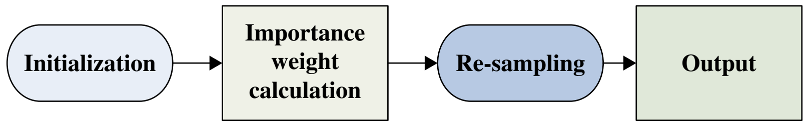

Fig. 4 Particle filter moving target tracking algorithm flow.

3. Resampling:

Computing the effective number of particles:

$$N = \frac{1}{\sum_a^N \omega_a^b}. \tag{17}$$

If $N < 1$, resampling and re-assigning new weights

$$\omega_a^b = \frac{1}{N}. \tag{18}$$

4. Outputting:

State estimation at time a:

$$x_a = E(x_a/z_a). \tag{19}$$

Posterior probability density:

$$P\left(\frac{x_a}{z_{1:a}}\right) = \sum_{b=1}^{N} \delta(x_a - x_a^b). \tag{20}$$

5. Judging whether it is over, if so, the tracking is over, if otherwise, repeating steps (2) to (4).[18]

The entire algorithm flow is shown in Fig. 4.

This is the basic process of the entire particle filter moving target tracking algorithm. Next, this paper will combine this algorithm to carry out the detection and tracking experiments of moving targets in the video of martial arts arena competitions.

4 Experiments on Detection and Tracking of Moving Targets in Martial Arts Arena Videos

4.1 *Experimental Method*

In this experiment, the conventional moving target detection and tracking method were first used to detect and track the moving target in the video of the martial arts arena, and the time taken to complete the tracking of the target movement track was recorded. Then combined with the particle filter moving target tracking algorithm based on non-scene target features to detect and track the same moving target in the same martial arts arena video. Also, recording the time used to complete the target trajectory tracking, and concluding by comparing it with the time used by the conventional moving target detection and tracking method. The conventional moving target detection and tracking algorithm first analyzes and processes the continuous video images of the martial arts arena, then extracts the required part of the martial arts movement from the background scene and uses a rectangular frame to lock the extracted movement target of the martial arts arena. The rectangular box will change accordingly with the passage of time and the movement of the target. The conventional moving target detection and tracking algorithm first extracts the required martial arts movement from the background scene, and uses a rectangular frame to lock the target, which will be generated with the passage of time, and the movement of the target corresponding changes. Finally, the frames in all video sequences that have changed can be connected to form the tracking trajectory of the moving target. However, the detection and tracking method of moving targets based on particle filtering of non-scene target features is no different from the conventional methods in the first few steps of moving target extraction in martial arts arena competitions. But in the step of connecting the rectangular boxes in all the video sequences that have changed to form the tracking trajectory of the moving target. Because the particle filter moving target tracking algorithm has the function of predicting the motion trajectory of the target according to the motion state of the target. Therefore, there is no need to wait for all rectangular boxes to be connected before forming the target trajectory. Instead, it analyzes the motion state of the object extracted from the video image of the moving object, and then directly predicts the motion trajectory of the object.[19]

4.2 *Detection and Tracking of Moving Objects in Video of Martial Arts Arena Competitions under Conventional Methods*

The first step of the experiment is to randomly select a video of a martial arts arena match and extract the required moving part of the martial arts target from the video. The extracted results are shown in Fig. 5.

It can be seen from Fig. 5 that the moving target has performed several simple martial arts movements in the video, and the movements have changed significantly. Next, using a rectangular frame to lock the moving target, as shown in Fig. 6.

From Fig. 6, we can see that the shape and position of the rectangular frame also change with the movement of the moving target, and the changes are obvious. By connecting all the changed rectangular frames, the motion trajectory of the rectangular frame and the motion trajectory of

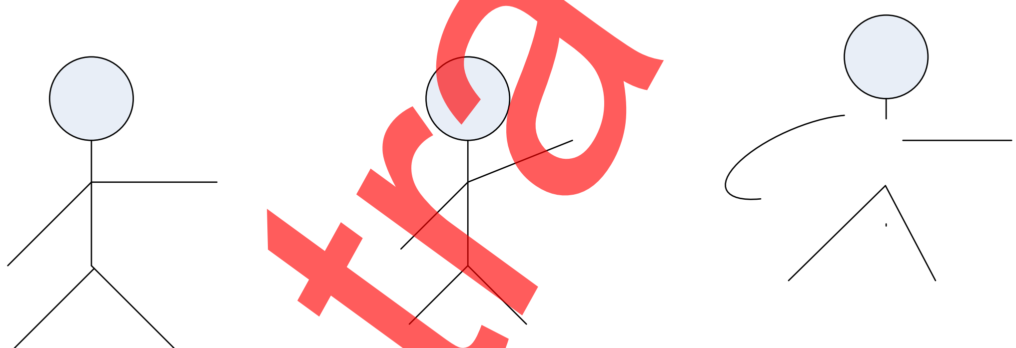

Fig. 5 Video sports target of martial arena competition.

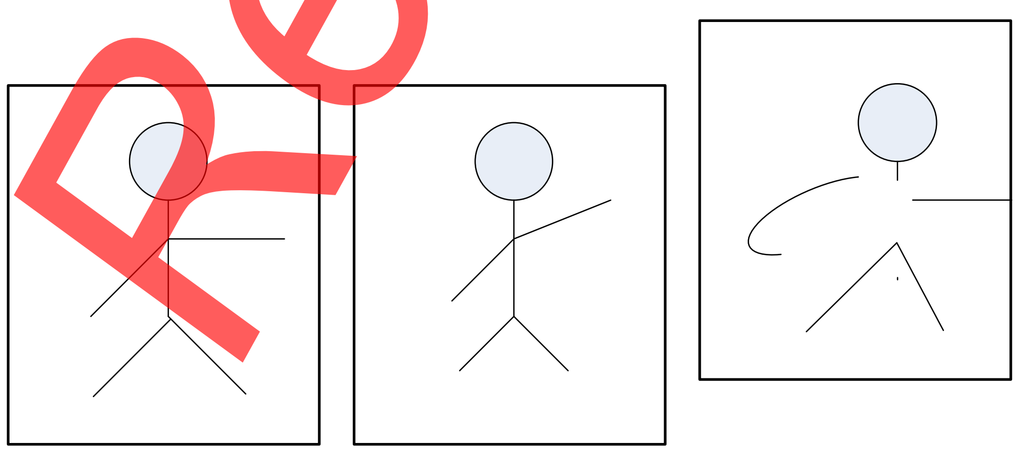

Fig. 6 Block diagram of moving target.

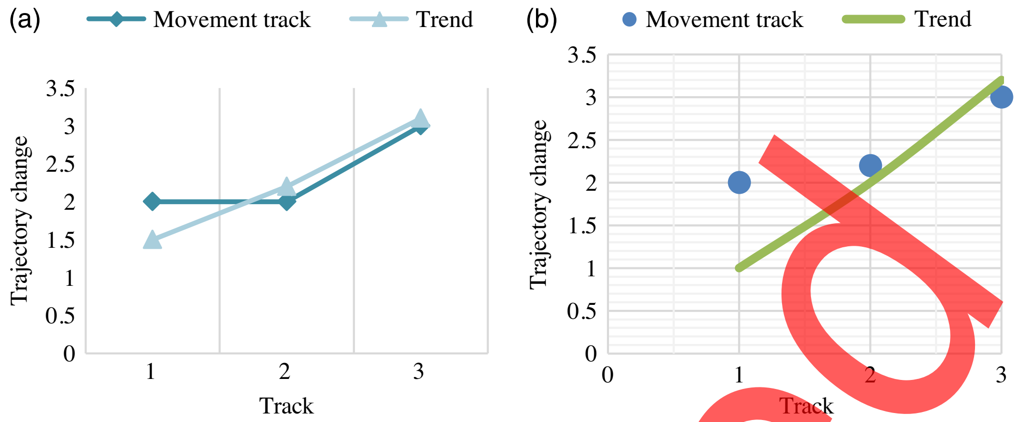

Fig. 7 Moving target trajectory. (a) Rectangular frame track and change trend and (b) moving target track and change trend.

the corresponding moving target can be obtained. The trajectory of the obtained moving target is shown in Fig. 7.

The dots in Fig. 7 can represent moving objects, and the lines connecting the dots are the moving tracks of the moving objects. Therefore, the movement trajectory of the moving target in the selected martial arts arena video can be clearly seen in Fig. 7. The relationship between the time we recorded and the time required to obtain the trajectory of the moving target and the running time of this method is shown in Fig. 8.

It can be seen from Fig. 8 that in the moving target detection and tracking in the martial arena video under the conventional moving target detection method in this experiment, the total running time of the method is 7 min, and the total time takes to obtain the target motion trajectory is 5 min.

4.3 *Target Tracking of Particle Filter Tracking Algorithm Based on Non-Scene Target Features*

After the tracking experiment of the moving target selected in the video of the martial arts ring competition under the conventional method is completed. In this paper, the tracking experiment of the same martial arts moving target based on the particle filter target tracking algorithm based on non-scene target features will be carried out. First, the frame of the selected moving target is also locked with a rectangular frame, and the movement trajectory change of the moving target is obtained according to the changes in the size, shape, and position of the rectangular frame. However, this step is different from the conventional method in that it does not need to wait

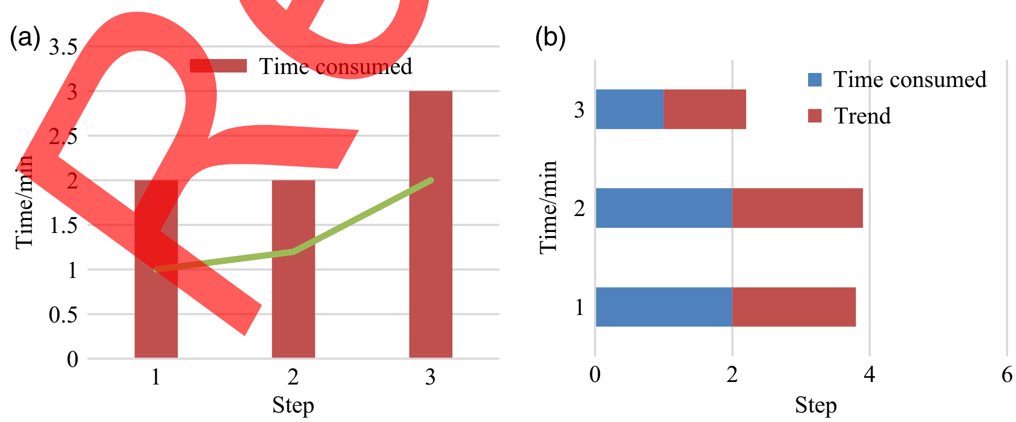

Fig. 8 Elapsed time. (a) Method running time and (b) deriving trajectory time.

for the completion of all the changes of the rectangular boxes to obtain the target motion trajectory. Instead, it directly predicts the change of the frame by analyzing the motion state of the moving target, that is, the change of the movement trajectory of the target.[20] The change trajectory of the rectangular frame and the target motion trajectory obtained this time are shown in Fig. 9.

It can also be clearly seen from Fig. 9 that the motion trajectory of the same target at this time is only slightly different from the target motion trajectory obtained by the conventional method, and there is no overall error. This shows that the particle filter target tracking algorithm based on non-scene target features is basically accurate for the trajectory tracking of moving targets. The running time of this method recorded this time and the time it takes to obtain the target motion trajectory are shown in Fig. 10.

It can be concluded from Fig. 10 that the total running time of the particle filter target tracking algorithm based on non-scene target features is 4.2 min. The total time spent to obtain the target trajectory is 3.5 min, which is 1.5 min less than the 5 min consumed by the conventional method.

This is the end of the whole experiment, and the conclusions are: without affecting the accuracy of moving target detection and tracking, compared with the conventional method, the particle filter target tracking algorithm based on non-scene target features saves 1.5 min of moving target trajectory tracking time. This conclusion shows that the non-scene-based particle filter target tracking algorithm has a certain effect of improving the efficiency of moving target detection and tracking in martial arts arena videos.

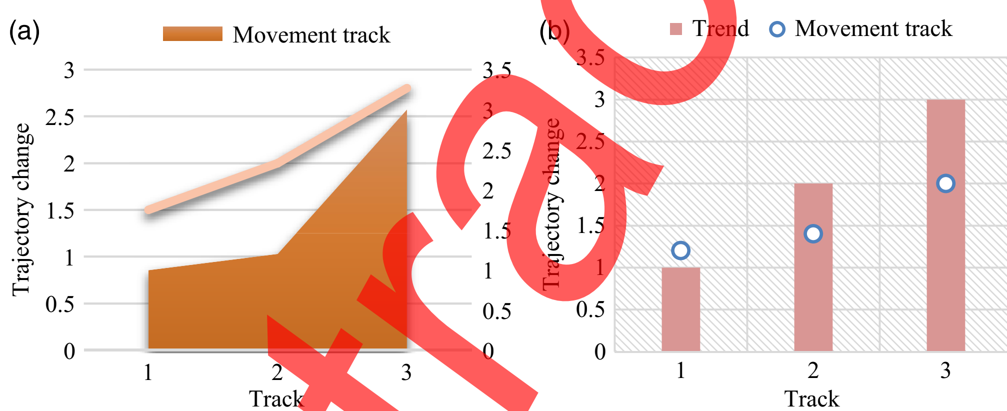

Fig. 9 Target trajectory. (a) Rectangle frame change trajectory and (b) moving target trajectory change.

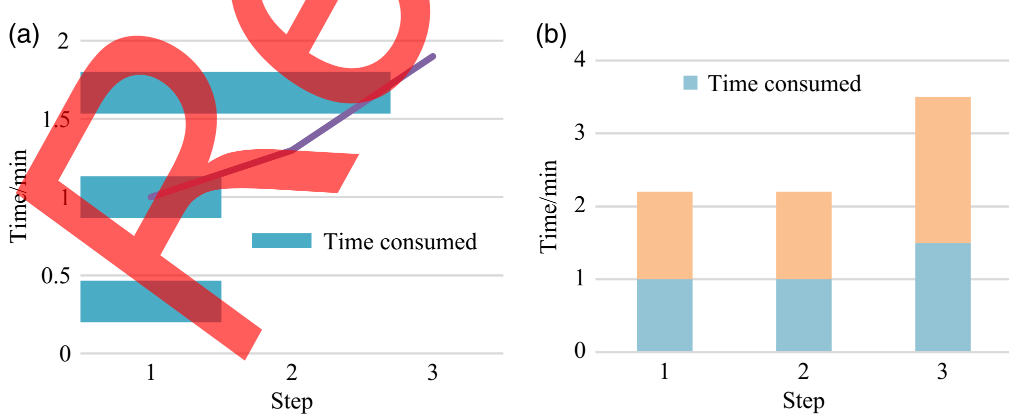

Fig. 10 Time consumption of particle filter tracking algorithm. (a) Algorithm running time and (b) time taken to derive the trajectory.

5 Discussion

Martial arts belong to sports, but higher than sports, this is because martial arts culture is one of the representatives of Chinese excellent traditional culture. Martial arts culture contains rich traditional Chinese cultural connotations and has distinct national sports characteristics. The martial arts arena refers to the arenas where early Chinese martial artists competed. Martial arts ring competitions are usually set up by the organizer, and the contestants compete in the ring according to the competition procedure. The winner can stay in the ring and accept the honor of the strongest martial artist.[21] In today's era, the inheritance and development of martial arts culture are in good condition, which is closely related to the active development of martial arts competitions.

Martial ring competition is an important form of inheritance and development of traditional martial culture, and it also plays an important role in the promotion and development of Chinese martial culture at home and abroad. To better develop the martial arts culture, sometimes it is necessary to extract the moving targets in the martial arts arena video to analyze the martial arts moves, so as to better improve the martial arts ability of the warriors. When extracting moving targets in martial arts arena videos and analyzing martial arts moves, reliable moving target detection, and tracking technology is needed to assist. Moving object detection and tracking is a technology that can clearly show the motion changes and motion trajectories of moving objects in the background scene through detection and tracking.[22] Conventional moving target detection and tracking methods include frame difference method and background difference method. With the advancement of science and technology, more and more advanced moving target detection and tracking algorithms have appeared. For example, particle filter target detection and tracking algorithms based on non-scene target features.

This paper mainly introduces the particle filter target detection and tracking algorithm based on non-scene target features in detail, including its basic concepts and specific algorithm operation processes. In addition, this paper also designs a moving target detection and tracking experiment in the video of the martial arts arena based on this algorithm. The experiment firstly uses the conventional moving target detection and tracking method to detect and track the moving target in the selected martial arts arena video. The steps include locking the target with a rectangular frame, connecting all the frames that have changed to obtain the movement track of the selected target, and finally recording the time spent to obtain the target movement track. Then the experiment uses particle filter target tracking algorithm to detect and track the same moving target. The steps include: locking the moving target with a rectangular frame. Then, frame change prediction and motion trajectory prediction of the target are obtained by analyzing the motion state of the target, and the predicted target motion trajectory is obtained by connecting the frames. Then, the obtained predicted target motion trajectory is compared with the motion trajectory obtained in the conventional method experiment to judge whether the prediction is accurate. Finally, the time taken to obtain the trajectory of the selected target based on this method is recorded, and compared with the time taken by the conventional method, the experimental conclusion is drawn. The experimental conclusion drawn in this paper is that the tracking time of the moving target trajectory of the particle filter target tracking algorithm based on the non-scene target feature is reduced by 1.5 min compared with the conventional method without affecting the accuracy of moving target detection and tracking.

6 Conclusion

Many conventional moving target detection algorithms exist, such as background difference method and Gaussian mixture model, but their functions are not very different, and there are still certain defects in technology. The particle filter target detection and tracking algorithm based on non-scene target features is a kind of algorithm by giving different weights to the sampled particles, the particle filter target detection and tracking algorithm based on non-scene target features is a kind of algorithm by giving different weights to the sampled particles. After forming the particle set, the probability density distribution of the state of the moving target is approximately estimated, and then the moving target detection and tracking algorithm of the target's motion trajectory is predicted. Compared with the conventional moving target detection and tracking algorithm, the biggest advantage of this algorithm is its ability to predict the moving state of the target. Because of this predictive ability, it does not need to wait for all target frame changes to complete and then connect the frames to track the trajectory of the moving target. Instead, the motion trajectory of the target can be predicted directly by analyzing the motion state of the target, and the prediction is basically accurate. The conclusion of this paper shows that the particle filter target tracking algorithm based on non-scene target features can improve the efficiency of moving target trajectory detection and tracking to a certain extent. This shows that the particle filter target tracking algorithm based on non-scene target features has certain application value in moving target detection and tracking. However, due to the limited research conditions and research level, the research of this paper also has certain limitations, such as the research angle and research method are still not comprehensive enough. It is believed that more excellent research related to moving target detection and tracking based on particle filter target tracking algorithm will emerge in the future academic circles, to better promote the development of moving target detection and tracking technology.

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