Computers and Electronics in Agriculture 123 (2016) 224–231

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

A multi-target trapping and tracking algorithm for *Bactrocera Dorsalis* based on cost model

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ARTICLE INFO

Article history:
Received 14 March 2015
Received in revised form 23 January 2016
Accepted 2 March 2016
Available online 12 March 2016

Keywords:
Multi-target tracking
Cost model
Bactrocera dorsalis
Counting algorithm

ABSTRACT

Researching a robust, high precision, stable performance and applicable target tracking method is of important theoretical significance and practical value. Using computer vision technology to detect and track moving object in video image is a kind of advanced target counting method and it is a research hotspot. That is a complex estimation problem and still faces enormous challenges. *Bactrocera dorsalis*, which is widely distributed in the southern area of China, has become the most serious pest and need to be controlled frequently. In this study, a *B. dorsalis* tracking and counting system based on computer vision has been built to find out the activity patterns of *B. dorsalis* so as to provide a better prevention and control of the pest. For counting the number of *B. dorsalis* passed through the monitoring area in real time, this study has analyzed the advantages and disadvantages of the mainstream methods, such as inter-frame difference method, background-difference method, optical flow tracking method, corner detection method, Mean Shift tracking method and other classical target tracking algorithms. Based on these analyses, this study has proposed a cost model for tracking *B. dorsalis*, which can track all the trajectories of *B. dorsalis* in the monitoring area in real time. A multi-*B. dorsalis* tracking algorithm based on this cost model and a *B. dorsalis* counting algorithm have been realized. Finally, the result of the experiment shows that the algorithm can solve the overlap of *B. dorsalis*. Additionally, a field experiment of the tracking algorithm has been carried out for 5 days in Guangzhou Yangtao Park. The number of *B. dorsalis* detected by computer system was 1570 and the manually counted number was 1591.The tracking accuracy is 98.7%.

1. Introduction

Target tracking is to estimate the motion state of the target using the data from the information source without any prior knowledge of target movement information, so as to predicate the position and the movement trends of the target (Hu, 2008; Yilmaz et al., 2006). Tracking moving objects is a complex estimation problem, and it belongs to the high-level image understanding category in computer vision. Early application was mainly in military research, which was the key technology for the precise weapon guidance. Now, with the in-depth study of image tracking technology, target tracking applications have penetrated into more and more areas, such as video surveillance, medical diagnostics. Researching a robust, high precision, stable performance and applicable target tracking method has important theoretical and practical value (Jiang, 2012; Jian and Odobez, 2007). But tracking moving objects based on the video stream is still a complex estimation problem, and it is faced enormous challenges (Tang, 2010; Xuan and Li, 2011).

Some researches have been done and they show that *Bactrocera Dorsalis* is widely distributed in the southern area of China and needed to be controlled frequently (Yu et al., 2010; Wan et al., 2011). Huang has done a survey in Huiyang, one of the cities in South China. The survey shows that the *B. Dorsalis*' damage area is accounted for 9.3% of fruit planting area. According to the survey, the most injured fruit is guava, whose injury rate is 87.4%. Followed by carambola, its injury rate is about 45–60%. There is no harvest without bagging (Huang and Qiu, 2009). As a result, it is necessary to take control of *B. Dorsalis*.

The current studies on *B. dorsalis* field monitoring are mainly by establishing pests monitoring, field trapping and gathering fruit rot shedding to count the number of *B. dorsalis* manually. This method

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http://dx.doi.org/10.1016/j.compag.2016.03.001
0168-1699/

has some disadvantages, such as heavy workload, low efficiency, poor reliability, low accuracy, and it cannot monitor the orchard pest situation fast in real time on a large-scale (Yu et al., 2010; Jiang, 2012). Some researchers used the infrared sensors to detect *B. dorsalis* (Li et al., 2015; Jiang et al., 2008). However, due to the weak light inside the device, this method could not accurately recognize the trapping pest. Some other researchers also used the infrared optical sensors to detect *B. Dorsalis* (Jiang et al., 2013; Liao et al., 2012; Okuyama et al., 2011). The overall counting accuracy is around 96%. However, it still could not further distinguish different types of pest trapped and observe the trapping procedure.

The number of *B. Dorsalis* is an important factor to keep control of the damage. Besides that, as with any pest insect, management of tephritidae relies on accurate identification of the target species (Walter, 2003; Satarkara et al., 2009) and the *B. Dorsalis* group comprises about 43 closely related species (Drew and Hancock, 1994). So it is necessary for the Agriculture experts to identify the species of the pests. On the other hand, most of the fruit orchards and farms are far away from the town and it is time-consuming for the experts to go there to collect data frequently and a remote observation system will be helpful. According to these requirements, Xiao devised a *B. dorsalis* trapping device based on CMOS image sensor (Xiao et al., 2015).

In order to achieve the equipment to count the number of *B. dorsalis* passed through the *B. dorsalis* monitoring area, this paper first analyzed the advantages and disadvantages of the mainstream methods, such as inter-frame difference method, background subtraction, optical flow tracking method, corner detection method, Mean Shift tracking method and other classical target tracking algorithms for tracking *B. dorsalis* (Wen and chen, 2007; Dai et al., 2009; Jiang et al., 2005; Zhao and Fan, 2007). On the basis of these theories, this paper uses multi-target tracking technology combined with practical application and proposes a cost model for tracking *B. dorsalis*, which can track all their trajectories in the monitoring area in real time. Then it develops a *B. dorsalis* multi-target tracking algorithm based on this cost model and proposes a *B. dorsalis* counting algorithm. Finally, this multi-target tracking algorithm is experimented in field.

2. The experimental analysis of mainstream algorithms on *B.dorsalis* tracking

The purpose of multi-target tracking is to divide the image data received by the camera into different observation sets or tracks corresponding to different information sources. Once the track is formed and confirmed, the number of targets being tracked and the target motion parameter corresponding to each track, such as position, speed, acceleration, and target classification characteristics, can be estimated. This section studies classical tracking algorithms combined with *B. dorsalis* application, and analyses the advantages and disadvantages of various algorithms.

2.1. Inter-frame difference method

The advantage of inter-frame difference method is that it can adapt better to the dynamic changes in the environment and be slightly affected by the light changes. And the algorithm is simple to meet real-time requirements. The disadvantage is that the stationary target cannot be detected, only the relative motion target can be extracted and only the approximate position of the target is detected, so this is imprecise. Using inter-frame difference method for *B. dorsalis* tracking is shown in Fig. 1. In Fig. 1(a), when *B. dorsalis* moves slowly, the algorithm can successfully track each *B. dorsalis*. In Fig. 1(b), when two *B. dorsalis* move relatively, the algorithm cannot distinguish the targets and lose them. In Fig. 1 (c) and (d), the *B. dorsalis* have left the tracking area, but the algorithm still believes *B. dorsalis* are present in the tracking area, which means a wrong target tracking.

The above result shows that the inter-frame difference method is heavily depending on the interval between two frames and the targets' movement speed. When *B. dorsalis* move quickly, the interval between two frames becomes large, and it produces no overlapping area between the two frames, resulting in the failure of extraction. Therefore, using this method is not suitable for the whole tracking process of *B. dorsalis*.

2.2. Background-difference method

Using a background-difference method for target tracking must first establish a model for the fixed background of the image at the beginning, and the accuracy of the model will affect the target detection and tracking. However, it is difficult to ensure that the background of the image is static due to the complexity of the environment. The labor cost will be very high to establish models for each *B. dorsalis* trapping device.

2.3. Optical flow tracking method

As an optical flow tracking method has high computational complexity, it need several seconds to process a $640 * 480$ size image, so it is difficult to meet the real-time requirements of *B. dorsalis* detection system. In addition, the optical flow tracking method cannot handle occlusion between multi-targets, therefore it is also not suitable for the detection of *B. dorsalis*.

2.4. Corner detection method

Among corner detection algorithms, Harris algorithm has high stability, high accuracy for L-shaped corner and it can be used to match objects with shape similarity in the image sequence, but it is not sensitive to noise. Since Harris algorithm uses Gaussian filters three times, it calculates corners at a slow speed. As shown in Fig. 2, small circles are corners detected by Harris, it can obviously be observed from the image that only a small number of corners are successfully located on the torsos of *B. dorsalis* due to the influence of light and built-in glass funnel in the trapping device. Therefore, when using this method for *B. dorsalis* detection and tracking, it is necessary to filter the result of Harris algorithm. To sum up, the effect of this method is not good.

2.5. Mean Shift tracking method

Fig. 3 shows the result of using the Mean Shift tracking algorithm for tracking *B. dorsalis*. In Fig. 3(a), when using Mean Shift algorithm to track a single *B. dorsalis*, it can track its trajectory and the tracking circle is closed to its contour. But in Fig. 3(b), when two *B. dorsalis* move to the same place or get close to each other, the tracking circle is close to their contour, which suggests that using Mean Shift algorithm cannot solve the problem of multi-objective occlusion, this will seriously affect counting numbers of *B. dorsalis*. Overall, Mean Shift algorithm is sensitive to the target contour, the result is better than other algorithms in single object tracking, but it must be improved to be applied to the counting of *B. dorsalis*.

3. A multi-target trapping and tracking algorithm for *B. Dorsalis* based on cost model

After analyzing the mainstream algorithms of multi-target tracking, it is found that those algorithms are deficient when