Tracking Ants Through Occlusions

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Abstract. The automated tracking of social insects, such as ants, could greatly increase the speed and reliability of gathering data used in studying their complex behaviors. Recently, data association based multiple-object tracking approaches have shown promise in improving tracking during occlusion. However, due to the high density and occlusion rate present in ant video, tracking is still prone to (1) identity switches with nearby ants coming in and out of long occlusions and (2) long periods of high occlusion where detection is difficult. We propose extending a previous data association based tracking method to address these issues. First, we introduce occlusion tunnels to constrain the possible choices allowed during the association process. Second, we propose an optical flow clustering method to detect and track ants during periods of known occlusion (or gaps) within the associated tracklets. Testing results on a 5,000 frame video of 50 ants shows that the inclusion of occlusion tunnels reduces tracking errors by 18% while our tracking with optical flow clustering reduces the number of missing detections by 59%.

1 Introduction

Social insects, such as ants, have become model systems for the study of division-of-labor, task specialization, adaptive networks, and collective decision making [1, 2], and automated tracking approaches could dramatically increase the amount and reliability of data used for complex analysis of their behaviors. Many previous insect tracking methods use Markov chain Monte Carlo methods, but these methods are often prone to drifting over long sequences due to challenges during occlusion [3, 4]. Recently, data association based tracking (DAT) approaches have become more popular as they incorporate more global temporal information [5] which could minimize the drifting. However, detection during occlusion is challenging and the tracking during occlusion is unknown. In this paper, we present a method to improve tracking during occlusion of multiple ants.

2 Method

2.1 Data Association Based Tracking

This work extends our previous work on DAT-based tracking [5]. A set of detections (given to the algorithm) is linked together into a series of tracklets, or short...
trajectories. The tracklets are then progressively associated (or linked) together over a series of stages into longer tracklets where at each stage more temporally distance associations are considered. A number of features are used to determine which tracklets should be associated together including color histograms, linear motion models, and irregular motion models using random walk theory. After the final stage of associations, we are left with a set of final trajectories describing the objects within the video. There are two challenges that we address in this paper. First, when a gap is large (in time), the risk of associating to incorrect ant is increased; ID switches are increased. Second, gaps of correct associations could be large and the tracking during those gaps is challenging.

2.2 Occlusion Tunnels

During and after a long occlusion, motion models alone are often insufficient as the occlusions may be long, making the motion predictions unreliable, and the high density of targets means appearance estimates may not always be sufficient in distinguishing between two possible matches. To reduce the number of possible matches and increase the likelihood of picking the correct match, we define a constraint based on a series of foreground detections where objects move through during occlusion. This is represented as a graph for a given set of objects that enter and exit.

To create this graph, foreground pixels are detected on each frame of the video using the color classification method of [4] followed by noise filtering with morphological operators. Foreground tunnels (possible paths for ants’ movement) are defined as a network of regions or connected foreground pixels. Regions that are spatially close within $\Delta t$ frames is connected. The value of $\Delta t$ can be adjusted based on the level of expected motion with respect to the frame rate. Occlusion tunnels are areas of the foreground tunnel where multiple paths merge (indicating occlusion of multiple objects) and later separate. Only associations between tracklets which enter/exit the same occlusion tunnel are allowed during the as-
The images above display the gap filling process. The middle image shows the results of watershed segmentation and the arrows show the average optical flow direction for each region. The image on the right shows the final results of clustering.

A sample occlusion tunnel is visualized in Figure 1. Occlusion tunnels also allow for an accurate estimate of the number of ants present in a given occlusion based on the number of tracklets entering and exiting.

2.3 Tracking with Optical Flow Clustering

After tracklet matching, there are large temporal gaps within the tracklets where the location of the ant is unknown. Tracking during these gaps is challenging due to the high level of occlusion. We assume that (1) the motion of ants are mostly translational, (2) motion of occluded ants is often unique and (3) the number of ants at each occlusion is known from the occlusion tunnel. When motion is translational, motion vectors of pixels in an object are identical. We estimate the motion vector at each pixel using optical flow [7]. Then, the region of occlusion is segmented into objects by assigning pixels to objects by performing k-means clustering. Note that the value of $k$ is computed from the occlusion tunnel. Clustering is performed with two criteria: (1) the mean of optical flow vector of all the pixels for each region and (2) the geodesic distance between pixels which promotes clustering of contiguous regions. To reduce computation time, the clustering is performed on the regions from watershed segmentation on the foreground connected component (refer to Figure 2.) The clustered regions are tracked by connecting when the prediction based on the optical flow is near the region in the adjacent frame. To minimize drifting during connection, the connections are simultaneously performed from two ends of gap. Any detections which are not linked are discarded as they are most likely noisy.

3 Results & Discussion

We evaluated our method on a 5,000 frame video sequence of Temnothorax rugatulus ants taken at 30 frames per second. There are 50 ants present for the entirety of the video, some of which are painted to assist in identification. To compare methods, we use the CLEAR-MOT metrics [8] which returns a single value describing the overall accuracy of the tracking called Multiple Object Tracking Accuracy (MOTA). The MOTA metric is comprised of three types of errors in multiple-object tracking: 1) miss-match errors, 2) false positives, and 3) misses.
Table 1. Results of tracking on a 5,000 frame video.

<table>
<thead>
<tr>
<th>Method</th>
<th>MOTA</th>
<th>MME</th>
<th>Misses</th>
<th>False Positives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>57.6%</td>
<td>60</td>
<td>104,388</td>
<td>0</td>
</tr>
<tr>
<td>Occlusion Tunnels</td>
<td>57.6%</td>
<td>49</td>
<td>104,427</td>
<td>0</td>
</tr>
<tr>
<td>Optical Flow Clustering</td>
<td>82.0%</td>
<td>131</td>
<td>43,053</td>
<td>1,161</td>
</tr>
</tbody>
</table>

First, the addition of occlusions tunnels to the baseline DAT method [5] reduced the number of miss match errors (MME) from 60 to 49 (18%). The number of ID switches (tracking drifting onto a wrong ant) reported in MME has been reduced from 7 with the baseline method to 1 with the occlusion tunnel. This demonstrates that the occlusion tunnels successfully eliminated the incorrect candidate tracklets with similar features of appearance and motion from consideration. After the tracklet association stage, our proposed method for tracking with optical flow clustering produced the correct tracking of 61,374 positions, reducing the rate of misses by 59%. Note the increase in false positives was less than 2% of reduction in misses. The majority of remaining misses occurs near the entrance, where up to five ants are simultaneously involved in severe occlusions. As a future work, we intend to improve our method for estimating the number of ants present within an occlusion, improving our gap detection assignment method, and providing additional analysis on more datasets.

References