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Real-time Visual Tracking for Cricket - Micro Robot Interaction Experiment

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Abstract—This paper describes about the trials of online trajectory tacking and recording for a cricket and a micro mobile robot based on particle filter from video sequence. Cricket show adaptive behavior after individual interactions and we attempt to construct a system for active interaction experiment for gathering the data related to the effect of interactions. In this manuscript, on-line tracking trials by using an applied particle filter during some interaction experiments with a micro mobile robot are done. Experimental results are shown and also discussed.

1. Introduction

Generally, pheromone behavior emerges when animals detect a particular pheromones. The insects with micro brain also show behavior selection based on the pheromone communication between individuals[1]. As a typical example, in behavior selection for the fighting behavior of Cricket (*Gryllus bimaculatus*), a neuromodulator (nitric oxide) for extracting a specific behavior program from polymorphic circuits plays an important role [2]. Moreover, the biological research results show that some kinds of biogenic amine play the roles to adjust aggressiveness and sensory efficacy in the insect's nucleuses. Based on these internal responses, it is observed that the cricket modified its own behavior selection adaptively in the fighting behavior[3],[4] and the behavior tendency depending on current contexts [5]. However, it is still unclear how spacio-temporally independent information, data and knowledge obtained from analytical results by neurophysiological and ethological research. Therefore, in order to understand such adaptability of the insect, we were attempting to build dynamic internal models [6], [7] for the crickets' fighting behavior. For more progress to understand adaptability of the cricket, we are intending to realize a condition adjustable interaction experimental system for gathering additional data related to such behaviors. As the fundamental issue in such system, recording the interaction behavior and trajectory tracking during the experiment must be equipped and such data are useful for analyzing the behavioral tendency. In this paper, we describe a real-time visual tracking for the interaction experiment with the cricket utilizing micro mobile robot.

2. A System for Active Interaction with the Cricket

In our current work, we are developing a prototype system for active interaction with the cricket utilizing micro mobile robot. Figure 1 shows the configuration of the prototype system. The system consists of a camera, a microphone, an IR signal transmitter and a operation pad which are connected to the laptop computer. Micro mobile robot which is named as *Ecobe* [8] equips two wheel and IR receiver. It is remotely operated via IR signal and the operator can set the control command by using the operation pad. Cricket responds to the other's pheromone (cuticular substances) and as the result of fundamental examinations [9], it was clear that the pheromone behavior would be attracted by some parts of the cricket's body. Therefore, we wrap the body of the micro mobile robot with the white paper and put the head part of the cricket on the fore side of its body. Figure 2 shows an example of the top view during an interaction experiments. We can confirm that the micro mobile robot with the male cricket's head part could interact with the male cricket and it could attract the pheromone behaviors.

For retaining natural conditions, cricket must be free from any artificial things because it would cause to give the stress to the cricket. It is an ideal condition however tracking for free motion of the cricket becomes difficult subject without any typical templates. Thus we must introduce a robust tracking method under mixed environment with natural creature and the artifact.

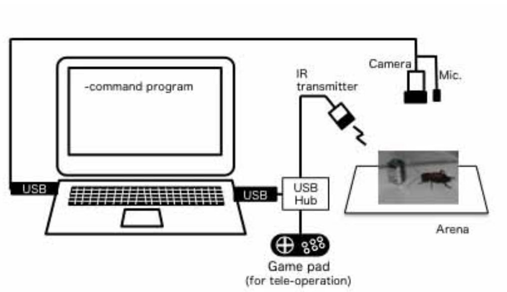

Figure 1: Prototype system for active interaction with the cricket

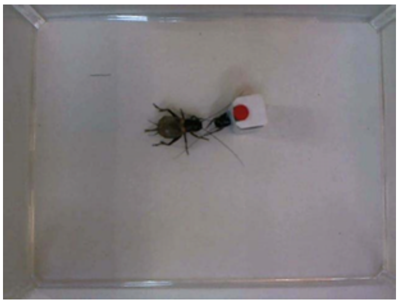

Figure 2: Top view of interaction experiment between a male cricket and operated micro mobile robot

3. Real-time Tracking of Cricket and Mobile Robot

As above-mentioned, cricket has no typical template for detecting and tracking as body size, body shape even in body color as a standard. Therefore, we considered the statistical approach would contribute to the sort of our tracking conditions. For marker-less tracking for free-motion of the cricket, we utilized particle filter approach[10], [11].

3.1. Particle Filter

3.1.1. Algorithm

The algorithm is as follows and $i = 1, \cdots, n$ and k indicate the number for specifying the particle and the captured frame, respectively.

1. generate the state vector of the particle $[p_1^0, p_2^0, \cdots p_n^0]$
2. repeat below process for every frame of the image.
   (a) estimate each state of the particle based on the dynamical model $Q(.)$ with system noise ϵ.
   $$\hat{p}_i^{k+1} = Q(p_i^k, \epsilon_{k+1}) \tag{1}$$
   (b) evaluate the likelihood using estimated state and observed state.
   $$w_i^{k+1} = R(p_i^{k+1} | \hat{p}_i^{k+1}) \tag{2}$$
   (c) calculate the probability of each particle based by nomalization.
   $$\eta_i^{k+1} = w_i^{k+1} / \Sigma_{j=1}^n w_j^{k+1} \tag{3}$$
   (d) renew the state vector $[p_1^{k+1}, p_2^{k+1}, \cdots p_n^{k+1}]$ by sampling with replacement.

3.1.2. Implementation

We apply the particle filter algorithm as color tracking subject. It is expected to chase the cricket and the robot based on likelihood evaluation. Therefore, we define a following equation to evaluate likelihood using the RGB value.

$$d_i = \sqrt{(r_i - R_{tg})^2 + (g_i - G_{tg})^2 + (b_i - B_{tg})^2} \tag{4}$$

Here, r_i, g_i and b_i are each RGB value on the pixel i. R_{tg}, G_{tg} and B_{tg} indicate each RGB value of the target for tracking respectively. The function w_i for each particle (pixel) is also expressed following function as a normal distribution.

$$w_i = \frac{1}{\sqrt{2\pi}} \sigma \exp\left(\frac{d_i^2}{2\sigma^2}\right) \tag{5}$$

Here, σ indicates the distribution value for normal distribution.

As the dynamic model of the particle, random-walk model is utilized because the motion of the cricket is fast and its tendency in each direction is not unpredictable one. Estimated state $\hat{p}_i^{k+1} = [\hat{x}_i^{k+1}, \hat{y}_i^{k+1}, \hat{u}_i^{k+1}, \hat{v}_i^{k+1}]^T$ for each particle is renewed by using the following transition calculation. $[x_i, y_i]^T$ and $[u_i, v_i]^T$ are position vector and velocity vector of the particle, respectively.

$$\hat{p}_i^{k+1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} p_i^k \tag{6}$$

If the position of any particle is set to the out of the image, the position is renewed as new generated one.

Moreover, tracking for the cricket and the mobile robot must be done simultaneously and be on-line processing. In order to extend above mentioned tracking method to two targets tracking, we set the two group of the particles. On each captured image, the processing for each particle group are done independently.

3.2. Outlier Analysis

For more accurate/robust tracking by the particle filter, we consider to introduce outlier analysis approach. Mahalanobis distance[12] is a distance measure based on the correlations between variables and it is utilized for cluster analysis and discriminate analysis. Mahalanobis distance is calculated by using the variables, its average value and covariance matrix. Here, we use the position of the particle ξ_i for outlier analysis with Mahalanobis distance and practical equations are as follows.

$$MD_i = \sqrt{(\xi_i - \bar{\xi})^T \, \Sigma^{-1} \, (\xi_i - \bar{\xi})} \tag{7}$$
$$\xi_i = [x_i, y_i]^T \tag{8}$$
$$\bar{\xi} = \frac{1}{n} \Sigma_{i=1}^n \xi_i \tag{9}$$
$$\Sigma = \frac{1}{n-1} \Sigma_{i=1}^n (\xi_i - \bar{\xi})^T (\xi_i - \bar{\xi}) \tag{10}$$

By this calculation, the average value of all MD_i is set to 1.0 and $MD_i = 0.0$ means the sample is the center of the

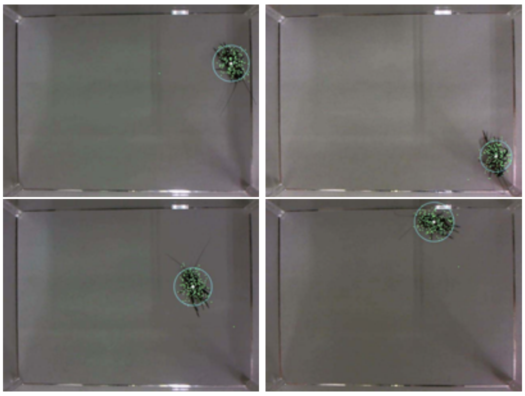

Figure 3: Snapshots of tracking a cricket

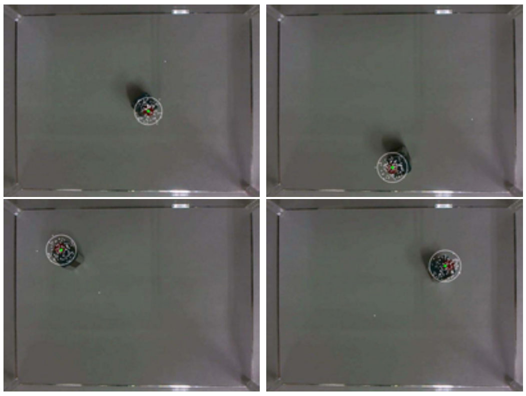

Figure 4: Snapshots of tracking a micro mobile robot

cluster. When the sample i takes larger value, there is possibility to be an outlier in the cluster. Here, we can select appropriate threshold for eliminate the outlier particles

4. Experiments

We conducts experiments utilizing proposed method. Macbook Pro (CPU: 2.6GHz Core 2 Duo, Memory: 4.0GB) is utilized as the computer We implemented the above mentioned method to our prototype system utilizing open source computer vision library : OpenCV. Here, the image size was set to 640×480[pixel] and the arena size was 200[mm] $\times$ 150[mm]. Target colors for tracking are set to black and red in RGB color feature expression. The image capturing was also done by 20 [fps]. The threshold value of the outlier analysis is set to 2.0.

At the beginning, we had basic experiments for confirming tracking performance. Figure 3 and 4 shows the results for cricket tracking and micro robot tracking, respectively. The target of former one is body color of the cricket (black) and the one of latter one is red circle marker on the top of the micro robot. The center of the circle indicates the average position of each group of the confident particles. The results shows it would work well for each target tracking.

At the next, we conduct tracking trials during interaction experiments. The operator maneuver the micro mobile robot by seeing the bird eye view of the arena. Figure 5 show an example of the interaction experiment between male cricket and the operated mobile robot with female cricket. We could confirm the tracking was done in several experimental trials correctly. The original/tracked video data and tracked trajectory data in 2-D space are stored on the storage of the computer on-line. Figure 6 also indicates

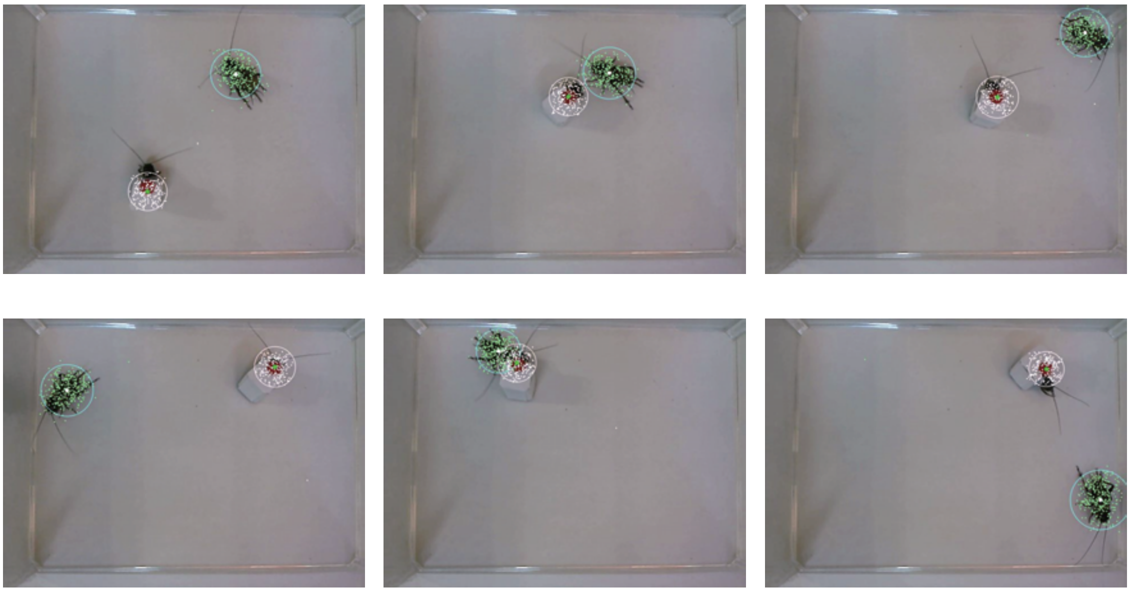

Figure 5: Snapshots of tracking processing by using particle filter

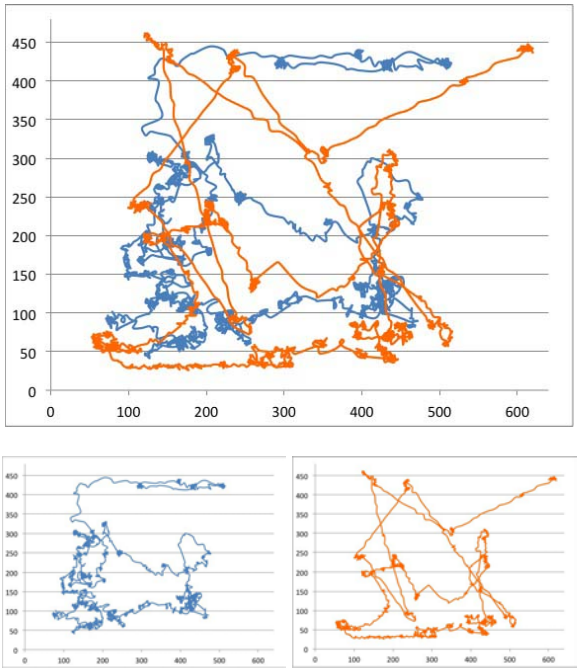

Figure 6: Tacked trajectories(upper). Independent trajectory of the male cricket (below left) and the micro mobile robot with female head(below right)

tracked trajectories during the same experiment.

5. Conclusion

In this paper, we describes an real-time/on-line tracking and recording method for the interaction experiment between a cricket and an operated micro mobile robot. For tracking each one of them during the interaction experiment , we utilized a particle filter algorithm as a statistical approach for visual tracking and introduced outlier analysis and elimination approach for more accurate tracking. Experimental results using prototype system were shown and the method

In our future work, this tracking method would be applied to semi-automatic interaction experiment based on visual feedback.

Acknowledgments

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