Efficiency Analysis of Preset Color Histogram in Mean-shift-based Crow Tracking

Takanori Koga, Kouji Ochiai, Noriaki Suetake and Eiji Uchino

***Abstract*—Rice-ducks fed in rice paddies for farming are preyed frequently by injurious birds such as crows. The aims of this study are to detect crows' predation-motion by using time-varying image processing techniques, and to prevent the crows' predation by driving the pest control system adaptively. In this study, we employ a well-known mean-shift algorithm for motion detection. In order to drive the equipments adaptively and adequately, a quick detection response to the crow's motion in the mean-shift algorithm is required. For realization of its quick detection response, we modify the mean-shift algorithm by using the preset color histogram calculated from the previous scenes. By the actual experiments, it is verified that the detection response of the mean-shift algorithm is improved by the preset color histogram while keeping the fundamental tracking performance.**

***Index Terms*—Rice-duck farming, Mean-shift algorithm, Object tracking, Crow, Preset color histogram.**

I. INTRODUCTION

IN recent years, as one of organic farming, rice-duck farming has attracted attention over the years in Japan [1]. In this farming, rice-ducks move around freely in the rice field during rice planting. Those rice-ducks not only weed the rice field but also eat the pests. Furthermore, those ducks' excrement becomes nourishment for the soil.

The rice-duck farming has the merits that farmers can reduce the amount of agricultural chemicals for insect deterrent and chemical fertilizer for forcing. This farming however has the demerits that the rice-ducks are hunted by harmful birds such as crows. This really is a serious economic damage to the rice-duck farmers [2].

Generally, crows are truly talented in learning how to break the traps installed for pest control system [3]. The pest control system for birds by using simple blast sound and light is thus limited in effectiveness.

To cope with this problem, we need to develop an adaptive pest control system. This system consists both of a flying crow tracking part and a bird pest control part as shown in Fig. 1.

The tracking part monitors the crow, which tries to hunt a rice-duck, by using time-varying image processing technique. The pest control part is driven by the trigger signal from the tracking part, and adaptively generates the evasion stimuli such as blast sound, laser beam, and so on [4].

Particularly, in this system, the crow tracking is very important. This is because the motion detection accuracy and its quick response to the crow's motion determine the overall pest control performance. In order to realize the accurate detection of the crow's motion with quick response, we propose, in this study, to use the mean-shift tracking algorithm [5][6][7], and to modify it.

Mean-shift algorithm is one of the well-known position tracking algorithms. It determines the position of a tracker by local search [8][9]. Current tracker's search area is determined based on the tracker's position in the previous frame.

Modification of the conventional mean-shift algorithm is strongly required for our purpose to accelerate the determination of a new tracker's position. So far, manual operation, background difference [10], and facial recognition by the Haar-like feature [11][12] have been used to determine the first position of the tracker.

We focus on the issues that the crows fly quickly in outdoors. If the speed of the target is slow, the edge of the target is extracted by the difference between frames. But in this study, as the speed of the target is fast, the whole body of the target is extracted. We determine the position of a tracker by using those characteristics.

Furthermore, a quickly-moving target may pass half of a screen during two or three frames. In order to realize an immediate detection of the target by using the mean-shift algorithm, we use the model with the color histogram obtained from the previous scenes. All crows have the same color. So a new crow has the same color as the one in the previous scenes. We call this histogram as "preset color histogram."

In this paper, we verify the effectiveness of the mean-shift algorithm with modification by the actual experiments. Specifically, we verify the accuracy improvement of the immediate start-up of tracking of crows without losing the fundamental tracking performance.

II. MEAN-SHIFT TRACKING ALGORITHM

The well-known mean-shift algorithm has a superior tracking performance, low computational complexity, and it can track a non-rigid object. In the mean-shift algorithm, a position of a target tracker is calculated by a gradient of the local distribution of weight. The weight is defined by the similarity of two color histograms. The weight of the pixel $\boldsymbol{x}$ is given by:

$$\omega(\boldsymbol{x}) = \sum_{u=1}^{m} \delta[b(\boldsymbol{x}) - u] \sqrt{\frac{q_u}{p_u(\boldsymbol{x}_0)}}, \quad (1)$$

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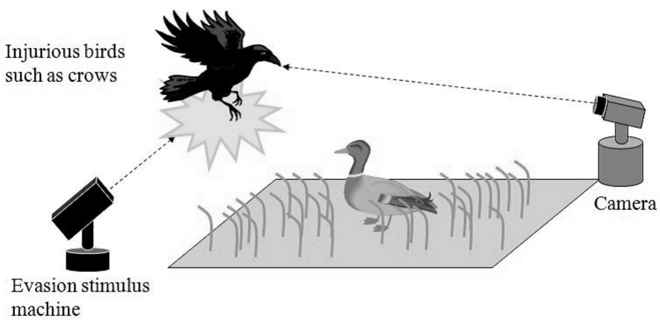

Fig. 1. A sketch of the proposed adaptive pest control system. This system consists both of a flying crow tracking part and a bird pest control part. The tracking part monitors the crow trying to hunt a rice-duck, by using the time-varying image processing technique, which generates a trigger signal to drive the stimulation device.

where q_u is a normalized histogram of a target, $p_u(\boldsymbol{x}_0)$ is a normalized histogram of the search area, $\boldsymbol{x}_0$ is the center of the search area, $b(\boldsymbol{x})$ is the number of histogram's bin including the luminosity of a pixel $\boldsymbol{x}$, and δ is a Kronecker's delta.

Mean-shift vector is calculated by:

$$\Delta\boldsymbol{x} = \frac{\sum_{i=1}^{N} K(\boldsymbol{x}_i - \boldsymbol{x}_0)\omega(\boldsymbol{x}_i)(\boldsymbol{x}_i - \boldsymbol{x}_0)}{\sum_{i=1}^{N} |K(\boldsymbol{x}_i - \boldsymbol{x}_0)\omega(\boldsymbol{x}_i)|}, \tag{2}$$

where $K(\boldsymbol{x})$ is a Epanechnikov kernel. Eq.(2) is repeatedly calculated until $\Delta\boldsymbol{x}$ becomes smaller than the pre-fixed threshold.

In order to determine the first position of a tracker, we use the difference of the image $\boldsymbol{I}$ obtained from three consecutive frames. Difference at frame $t-1$ is given by the logical product of the difference between $\boldsymbol{I}(t-2) - \boldsymbol{I}(t-1)$ and $\boldsymbol{I}(t-1) - \boldsymbol{I}(t)$.

In case when the speed of the target is fast, the travel distance of a crow in one frame is longer than the size of a crow. So the whole figure of a target is extracted by the difference between frames.

If the size of the extracted area is more than a threshold, the mass of pixels is regarded as the area of a crow. The normalized histogram of the target is obtained by using the intensities of this area.

Once the tracking is started, any new tracker is not created even if any difference is detected in the search area. On the other hand, if any difference is not detected in the search area, the tracking is stopped and the tracker is extinguished. Therefore, when the tracker loses a crow by tracking errors, the tracker disappears automatically. Then a new tracker is positioned by the difference between the frames when a new crow is detected.

III. Introduction of Preset Color Histogram

If a misalignment of a search area occurs when a new crow is detected, a tracker loses a crow. Even if the tracker loses a crow, a stable tracking can be realized by re-capturing the target. However, a crow can pass half the size of a screen during the repetition of re-capture.

To prevent predation by crows, the pest control system should be driven as fast as possible. This is very important not to let crows notice the relationship between the predation motion and the evasion stimuli such as blast sound, laser beam, and so on. Therefore the rapid and accurate tracking is required after a crow begins to move.

Crows have little color difference of appearance. Furthermore, it is hardly affected by the change of light, because the whole body of a crow is almost black. Thus, the crow's color in the next scene can be predicted from the crow's color observed in the previous scene.

The preset color histogram is made by the following procedures, which is used as the histogram of the target crow.

1) An area, estimated as a crow at time t, is extracted by calculating an inter-frame difference.
2) A color histogram is made by using the color information of the extracted area.
3) The mode μ_t and the variance ρ_t are calculated from the color histogram.
4) The time average is calculated by:

$$\mu_a = \frac{1}{m}\sum_{t=1}^{m} \mu_t, \tag{3}$$

$$\rho_a = \frac{1}{m}\sum_{t=1}^{m} \rho_t, \tag{4}$$

where m is the number of the current frames.
5) Calculate a normal distribution $f(\mu_a, \rho_a)$. This distribution is used as a preset color histogram.

The color histogram of a crow has a monomodal distribution because a crow's color is solid. Thus, the form of the histogram can be approximated by a normal distribution.

IV. Evaluation Indices

We confirm the characteristics, and verify the effectiveness of the preset color histogram in the modified mean-shift algorithm. First, the fundamental tracking performance is evaluated by using a true positive rate (TPR), a false positive rate (FPR), and a tracking accuracy.

A. *Evaluation of fundamental tracking performance*

At first, the fundamental tracking performance is evaluated by using a true positive rate (TPR) and a false positive rate (FPR). In this regard, the correct position is determined by human by tracing the center of the crow in advance.

If the tracker includes the correct position of a target in it, this case is a true positive (TP). If the tracker does not include the correct position of a target in it, this case is a false negative (FN). If there exists no target, but the tracker exists, this case is a false positive (FP). If there exists neither target nor tracker, this case is a true negative (TN).

The true positive rate (TPR) and the false positive rate (FPR) are defined as follows:

$$TPR = \frac{TP}{TP + FN} \times 100(\%), \tag{5}$$

$$FPR = \frac{FP}{FP + TN} \times 100(\%). \tag{6}$$

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TABLE I
FUNDAMENTAL TRACKING PERFORMANCES WITH OR WITHOUT USING THE PRESET COLOR HISTOGRAM.

	Tracking without Using the Preset Color Histogram	Tracking with Using the Preset Color Histogram
TPR	82.8%	88%
FPR	1.4%	2.7%

Another performance evaluation index is a distance between the correct position and the tracker's position. Evaluation by using this distance is carried out for the case of TP.

The distance is defined by $|\boldsymbol{x}_a - \boldsymbol{x}_t|$. $\boldsymbol{x}_a$ and $\boldsymbol{x}_t$ are the correct positions of the target and the center position of the tracker, respectively. The distance is calculated for every crow. The number of frames used in this experiment is 753.

B. *Evaluation of an immediate start-up of tracking*

The rapidness of the start-up of tracking is evaluated based on the number of frames when a crow begins to move until the tracker captures the crow. This is a period until the tracker succeeds to capture the correct position of the crow at least three consecutive frames. If a crow intersects another crow, it is reset.

Two movies were used in this experiment. One movie is bright in background, and the other is gloom.

V. Experimental Results

Fundamental tracking performances by TPR and FPR with or without using the preset color histogram are given in Table I. The left column shows the case without using the preset color histogram. The right column shows the case with using the preset color histogram.

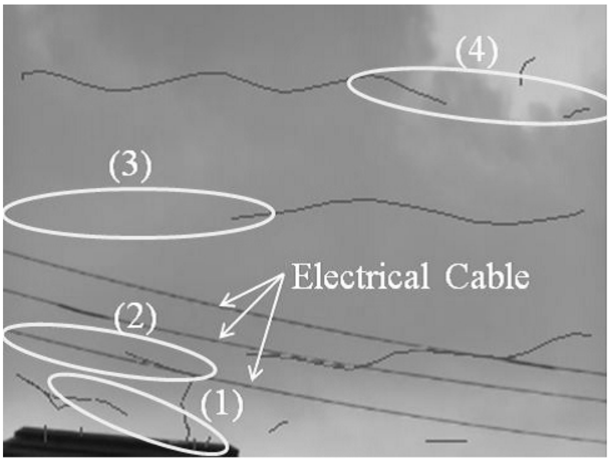
The tracking accuracy is high in each case with or without the preset color histogram. This shows that the preset color histogram does not affect the fundamental tracking accuracy. The tracking with using the preset color histogram is a little bit better though than the one without using it.

We also measured the distance error between the correct position and the tracker's position. In case without the preset color histogram, the average of the distance error was 9.3 pixels. And in case with the preset color histogram, the average of the distance error was 8.1 pixels. Both errors are almost the same. This shows that the tracking accuracy is independent of using the preset color histogram.

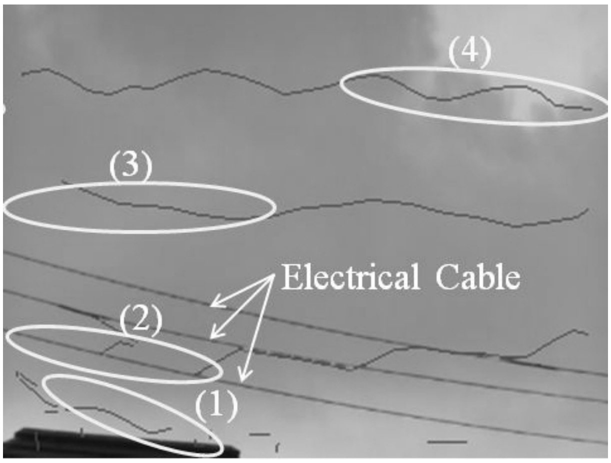
Next, the quick response to the crow's movement is evaluated according to the number of frames until the stable tracking is established.

The flying-trajectories of crows are shown in Figs. 2(a) and 2(b). Fig. 2(a) show the tracking trajectories in the case without the preset color histogram, and Fig 2(b) show those with the preset color histogram. The ellipses in the figures show the parts that the tracking trajectories are different in Figs. 2(a) and 2(b). The numbers beside the ellipses are the orders of crow's frame-in.

The directions of crow's flight are, (1): from the bottom to the up-left, (2) and (3): from the left to the right, (4): from the right to the left. In cases of (3) and (4) in Figs. 2(a) and 2(b), the tracking with the preset color histogram is better than the one without it.



(a)



(b)

Fig. 2. The tracking trajectories in case with or without the preset color histogram for movie 1 (Bright background). (a) Without the preset color histogram. (b)With the preset color histogram.

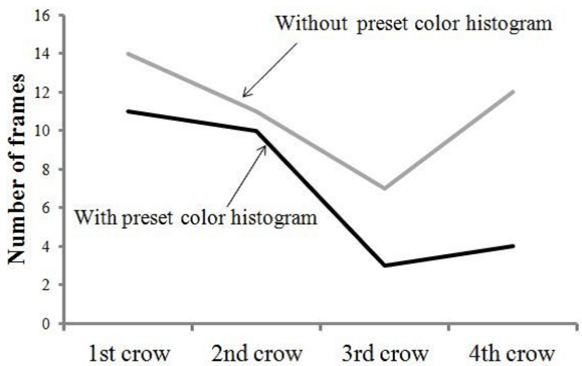


Fig. 3. Number of frames until the stable tracking is established in case with or without the preset color histogram for movie 1 (Bright background).

In case of (2) in Fig. 2(b), the tracking was failed. It is supposed that one factor of failure is an existence of an electrical cable stretched at the bottom of the scene.

The number of frames until the tracking becomes stable is shown in Fig. 3. The numbers assigned to crow correspond to the numbers in Fig. 2. From Fig. 3, it can be said that the tracking performance is better in case with the preset color histogram.

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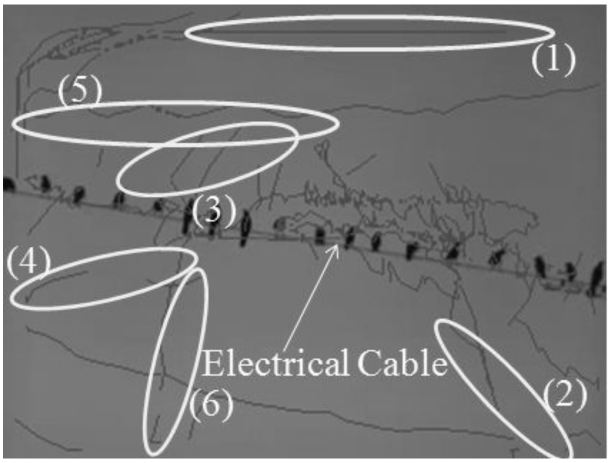
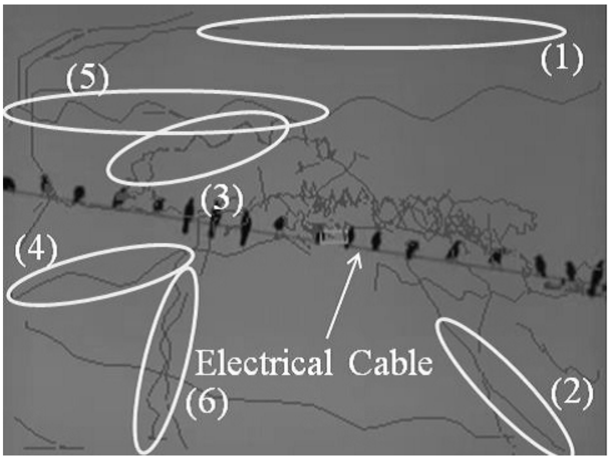


(a)



(b)

Fig. 4. The tracking trajectories in case with or without the preset color histogram for movie 2 (Gloom background). (a) Without the preset color histogram. (b) With the preset color histogram.

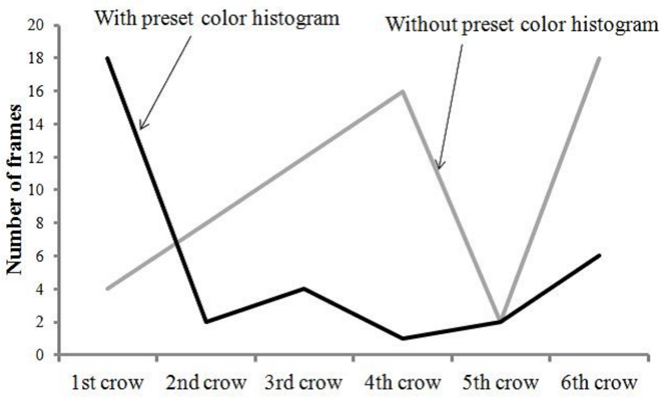


Fig. 5. Number of frames until the stable tracking is established in case with or without the preset color histogram for movie 2 (Gloom background).

The experiments were also carried out for movie 2. Movie 2 was recorded in a gloom background. The results are shown in Figs. 4 and 5. Also in this movie, the tracking with preset color histogram is better than the one without it.

In case of movie 2, the trackers were sometimes changed off with each other (from crow to crow) when the crows' flight trajectories crossed over.

From all those results, it can be generally said that the tracking with preset color histogram is better than the one without it.

VI. Conclusions

In this paper, we verified the effectiveness of the preset color histogram in the mean-shift-based crow tracking algorithm. As a result, it has been shown that the number of frames, until the stable tracking is established, can be reduced by using the preset color histogram. This indicates that the mean-shift algorithm was modified successfully to speed up the capturing of object.

Future works are, first, to improve the tracking accuracy, and further to introduce an idea of tracking inertia to reduce the conflictions of trackers.

References

[1] T. Fujie, N. Inoue and Y. Kishida, "Cropping Behavior of Farm Households Cultivating Rice Using "Aigamo" Crossbred Ducks: A Focus on Risk Aversion and the Effect of Experience Accumulation," *The Farm Management Society of Japan*, vol. 43, no. 1, pp. 1-11, Jun., 2005

[2] K. Takayama, S. Shimabukuro, M. Yoshida and K. Akai, "Protection of Aigamo Eggs from Injurious Crows," *Bulletin of the Faculty of Agriculture, Kagoshima University*, vol. 61, pp. 23-27, 2011

[3] E. Izawa, "Social Ecology of Corvids," *The Japanese Journal of Animal Psychology*, vol. 61, no. 1, pp. 55-68, 2008

[4] Y. Kobayashi, N. Ezaki, H. Takizawa, S. Mizuno and S. Yamamoto, "Study on Detection of Crows in the Farm by Image Processing," *IEICE Transactions on Information and Systems*, vol. J91-D, no. 2, p. 243, Mar., 2008

[5] D. Comaniciu, V. Ramesh and P. Meer, "Real-Time Tracking of Non-Rigid Objects Using Mean Shift," *IEEE Computer Vision and Pattern Recognition*, vol. 2, pp. 142-149, 2010

[6] K. Okada, "Mean Shift: from Theory to Application," *Computer Vision and Image Media*, vol. 2008, no. 27, pp. 401-414, Mar., 2008

[7] Y. Cheng, "Mean Shift, Mode Seeking, and Clustering," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 17, no. 8, pp. 790-799, Aug., 1995

[8] O. Ryosuke, M. Yoshifumi, F. Hironobu, A. Tokihiko and K. Toshiaki, "Vehicle Tracking Using Cooperative Multiple Scalable Mean-Shift Trackers," *Meeting on Image Recognition and Understanding (MIRU) 2005*, pp. 419-424, Jul., 2005

[9] K. Yoda, M. Sato and S. Yonemoto "Multitarget Tracking Using Mean-shift with Particle Filter Based Initialization," *Forum on Information Technology*, vol. 7, no. 3, pp. 157-158, Aug., 2008

[10] T. Yoshiyuki, "Background Differencing Technique Based on the Status of Reference Pixels," *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences*, vol. J88-A, no. 11, pp. 1226-1234, Nov., 2005

[11] D. Takeuchi, Y. Ito, A. Yamashita and T. Kaneko "Multi-Viewpoint Person Tracking Based on Face Detection of Arbitrary Pose and Mean-Shift Algorithm, " *ITE Technical Report*, vol. 33, no. 11, pp. 69-72, Feb., 2009

[12] P. Viola and M. Jones, "Rapid Object Detection Using a Boosted Cascade of Simple Features," *IEEE Computer Vision and Pattern Recognition*, vol. 1, pp. 511-518, 2001

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