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Dynamic Vision Based-Tracking for Behavior Observation

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Abstract– In recent years, behavior observation for moving objects such as cell, bacteria and insect is important to understanding the ecology of biological characteristics and habits in the medical filed. In this paper, we propose new technique to construct method of image tracking for the creature observation under the various environments. However, since the brightness change occurs by influence of illumination change or irregular moving of tracking target, we propose new tracking method to have applied the orientation code matching with multi-templates method which is a robust method to the influence of the illumination change. Further, in order to solve problem which comes from irregular moving of the tracking target, we estimate the position of tracking target with high accuracy based on the particle filter. Finally, through experiments, we show effectiveness of our method.

1. Introduction

Tracking device system for observe creature is attention to various fields and have been research widely. Especially, to observe cell, bacteria and microorganism in the medical field is important to understanding the ecology of biological characteristics and habits, further, these are expected to application to the drug development. In this paper, we use an image processing technology and aims to construct a technique of the tracking for the creature observation under the various environments. There are many traditional image processing tracking methods [1, 2] using a method based on the template image or background subtraction method. However, when observe creature which used an image processing, there are issues change image brightness by illumination variation, background change over time and the irregular moving of the tracking target. To solve these problems, we proposed the tracking method to have applied the orientation code matching which is a robust method to the influence of the illumination change. However, the problem which is irregular moving of the tracking target and the object which shape similar to a tracking target are unresolved. In here, we introduce new tracking method that combined the orientation code matching using a multiple templates and the particle filter. Then, we introduce the tracking method that performs high accuracy position estimation. Specifically, we use orientation code matching which is robust method to the influence of the illumination change. Furthermore, we treat multiple templates that include the past orientation code information and prevent false detection by the background information. Moreover, we give the position estimate of the tracking target which we used a particle filter for distinction similar shape object or the irregular moving of the tracking target.

2. Detection Method by Orientation Code Matching

We describe detection method of tracking target based on orientation code. Orientation code [3,4] is not for use as a direct assessment of the target pixel brightness value, use as an evaluation value of the quantized gradient direction in the vicinity of the target pixel. Therefore, it is robustness for a brightness change of the image illumination. First, we explain how to calculate the orientation code c_{ij}. In here, we define the target pixel brightness value $I(i,j)$ at position (i,j) and calculate horizontal gradient $\nabla I_i = \partial I / \partial i$ and vertical gradient $\nabla I_j = \partial I / \partial j$. Then, equation (1) defines the gradient angle θ_{ij} given by

$$\theta_{ij} = \tan^{-1}\left(\frac{\nabla I_j}{\nabla I_i}\right) \tag{1}$$

where ∇I_i and ∇I_j are calculated by Sobel operator. Orientation code c_{ij} is obtained by using gradient quantization θ_{ij} quantized by quantization width Δ_θ as follows:

$$c_{ij} = \begin{cases} [\theta_{ij} / \Delta_\theta] & \text{if} \left|\nabla I_i\right| + \left|\nabla I_j\right| > \Gamma \\ N = 2\pi / \Delta_\theta & \text{otherwise} \end{cases} \tag{2}$$

where N is the number of quantization, Γ is a threshold that determined in order to remove a low gradient. The excluded pixels determine N=16 as an invalid code. Orientation code evaluates 16 levels from 0 to 15. Then, based on the conceptual diagram of quantized orientation code shown in Fig. 1, we obtain orientation code from (2). In addition, the upper part of Fig. 2 shows the daphnia which have each different image brightness values. From Fig. 2, it follows that orientation code is robust to the influence of the illumination change.

In here, we show the detection method of tracking target. First, we define the template image f and the target

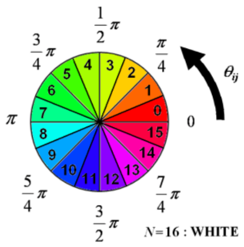

Fig. 1. The concept of orientation code.

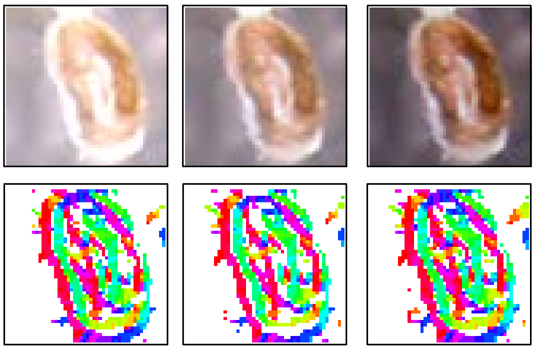

Fig. 2. Robustness for illumination change.

image g, both size of $M \times M$. Then, we compare orientation code between the template image and the target image. Further, we calculate the absolute residuals of orientation code which correspond pixels of template image and target image. Then, we define the mean of absolute residuals d_k which is calculated sum of absolute residuals divided by the total number of template image pixels. Furthermore, we calculate value of inverse of the mean of absolute residuals from (3), (4).

$$S_k = \frac{1}{d_k} \quad , \quad d_k = \frac{1}{M^2} \sum_{M \times M} d(c_f, c_g) \tag{3}$$

$$d(a,b) = \begin{cases} \min\{|a-b|, N - |a-b|\} & \text{if } a \neq N, b \neq N \\ N/4 & \text{otherwise} \end{cases} \tag{4}$$

In order to identify similarity area to the template image using S_k in (3), multiple templates are applied. Namely, we extract candidates for tracking target using multiple templates that matched in the past. First, suppose that the orientation code information in frame interval does not suddenly change. Then, to use multiple templates that matched tracking target before time k and prevent false detection due to the background information. In fact, we treat multiple templates by comparing the orientation code information between target image and n pieces template image. Then, we calculate the mean of absolute residuals between target image and template image. Then according to (5), we calculate mean of the d_k by n piece of template image. According to (6), similarity is calculated by inverse of the mean of absolute residuals $\bar{d}_k$.

$$\bar{d}_k = \frac{1}{n} \sum_{\hat{k}=k-n}^{k-1} d_{\hat{k}} \quad , \quad d_k = \frac{1}{M^2} \sum_{M \times M} d(c_{f(\hat{k})}, c_g) \tag{5}$$

$$\bar{S}_k = \frac{1}{\bar{d}_k} \tag{6}$$

where $c_{f(\hat{k})}$ means the orientation code which matched at time k. In here, we extract any number of large areas of similarity $\bar{S}_k$ as candidates for tracking target. In Section 4, we show the recognition method of tracking target which is extracted from the candidate.

3. Position Estimation Method by Particle Filter

In the past, we have been proposed a tracking method [5] that combined extended Kalman filter for distinguish similar shape object. However, when tracking the creatures, observed estimate accuracy degradation due to nonlinear motion, and sometimes occur false detection for tracking target. Therefore, in order to estimate position that corresponds to a nonlinear motion, we improve tracking accuracy by using a particle filter [6] that is one of the nonlinear estimation filter. To make a particle filter which we use in this paper, we design a few of likelihood functions using both of orientation code histogram and constant velocity.

First, we show a likelihood function L_H which uses orientation code histogram for tracking target. Then, we generate orientation code histogram which contain valid code in the template image and target image. According to (7), we assess orientation code histogram between template image and target image, using a histogram intersection method. By using a histogram intersection method, we use evaluation value which correspond sum of small the orientation code template image and target image.

$$H = \sum_{h=0}^{N-1} \min(o_f(h), o_g(h)) \tag{7}$$

where $o_f(h)$ is number of orientation code h in template image, $o_g(h)$ is number of orientation code h in target image. The example of $o_f(h)$ and $o_g(h)$ are show in Fig. 3.

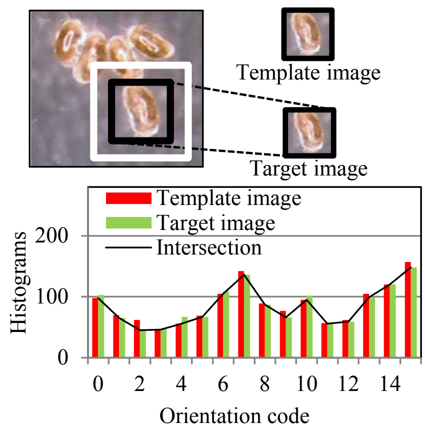

Fig. 3. Histogram of intersection method.

Then, we define a likelihood function L_H as follows:

$$L_H = \exp(-\frac{(H'-H)^2}{2\sigma^2}) \tag{8}$$

where σ represents the dispersion of the particle. From (8), a likelihood function L_H is given by the residual between evaluation value H that obtained from the equation (7) and the total number of valid codes contained in template image.

Furthermore, we define the likelihood function L_d of constant velocity linear motion prediction, and then estimate the tracking target position from tracking target motion. To estimate the tracking target position at time k, we use matched tracking target position at time k-1 and k-2. Then, based on the following (9), we calculate estimate velocity $\hat{u}_k, \hat{v}_k$ at time k.

$$\hat{u}_k = (i_{k-1} - i_{k-2}) / \Delta T \ , \ \hat{v}_k = (j_{k-1} - j_{k-2}) / \Delta T \qquad (9)$$

where ΔT is a sampling time. Further, we calculate the position (i'_k, j'_k) at time k using velocity $\hat{u}_k, \hat{v}_k$ as follows:

$$i'_k = i_{k-1} + \hat{u}_k \cdot \Delta T \ , \ j'_k = j_{k-1} + \hat{v}_k \cdot \Delta T \qquad (10)$$

In here, we define the second likelihood function L_d as follows:

$$L_d = \exp\left(-\frac{\{\sqrt{(i'_k - i_{p|l})^2 + (j'_k - j_{p|l})^2}\}^2}{2\sigma^2}\right) \qquad (11)$$

where let $(i_{p|l}, j_{p|l})$ mean the distance of particle coordinates at the particle number l and let (i'_k, j'_k) show the estimated position.

Then, we generate the synthesis likelihood function L in the following (12) by using two likelihood functions L_H and L_d. Namely, we estimate the position of tracking target based on new likelihood function L which is combined of both orientation code information and motion prediction.

$$L = L_H \cdot L_d \qquad (12)$$

4. Robust Tracking Method

In this section, we consider an evaluation value that combined similarity $\bar{S}_k$ that is detected by both of orientation code matching using multiple templates and the estimated position (i_p, j_p) based on the particle filter in order to the matching of tracking target.

First, we setup the size of $S \times S$ pixels as search area that centered on the particle coordinate (i_p, j_p) and detect the tracking target by orientation code matching using multiple templates in this search area. Then, we define position (i_{km}, j_{km}) that is candidate tracking target. Now, we define λ_{km} as an evaluation value given by (13). λ_{km} means a normalization of distance candidate tracking target position and estimated position calculated by (12). Further, the value of λ_{km} is in from 0 to 1. Then, Fig. 4 shows the concept of (13).

$$\lambda_{km} = \frac{\sqrt{(i_p - i_{km})^2 + (j_p - j_{km})^2}}{\sqrt{(i_p - i_g)^2 + (j_p - j_g)^2}} \qquad (13)$$

where km means the number of candidates and (i_g, j_g) represents the candidate's position that is farthest from the estimated position. Next, we define the following evaluation function given by the distance λ_{km} and similarity $\bar{S}_k$ of the candidate tracking target.

$$\min\{E_{km} : E_{km} = \alpha \cdot \bar{S}_{km} \cdot \frac{N}{2} + (1-\alpha) \cdot (1 - \lambda_{km})\} \qquad (14)$$

Then, choosing the tracking target that has maximum evaluation value in (14), we conduct target tracking.

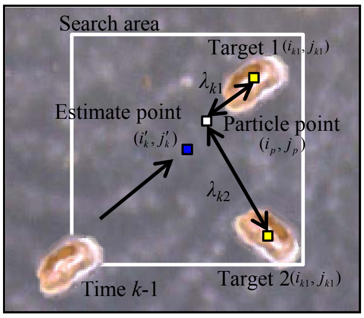

Fig. 4. The concept of (13).

4. Experimental Results

In this section, we introduce experiment results based on robust tracking method which we proposed in this paper, and then show effectiveness of our proposed method. In here, we treat two moving creatures such as

(1) Daphnia in the water, and
(2) Mosquitos which are flying under random walk

4.1. Daphnia

In a laboratory dish, we put 5 daphnia and then track one of them. As the experimental conditions, suppose that search area S is 51 × 51 pixels, matching area M is 15 × 15 pixels, the number of templates n is 3, threshold $\Gamma = 60$, variance of the particles σ is 25 and the weight α is 0.9. Fig. 5 denotes the orientation code image of Fig. 6 and Fig. 6 shows the tracking result.

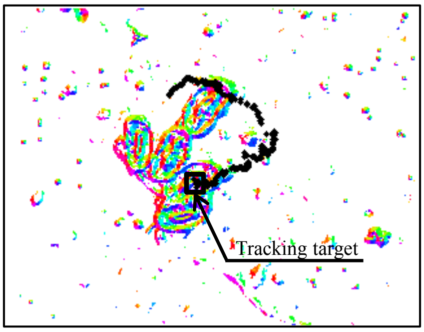

Fig. 5. Orientation code image of Fig. 6.

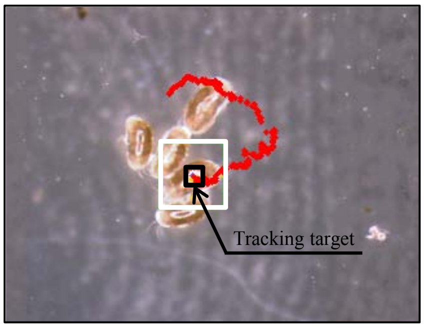

Fig. 6. Tracking result of a daphnia.

In Fig. 6, a large frame describes the search area, a small frame shows the matching area, and the dashed line means the trajectory of tracking target. According to the matching trajectory, our proposed method detects and tracks the moving target.

4.2. Mosquitos

We setup 11 mosquitos in a transparent plastic container size of High 123mm × Wide 194mm × Depth 54mm. Then, we take an animation of flying mosquitos by video camera at a constant value focus. In here, search area S is 81 × 81 pixels, matching area M is 11 × 11 pixels, the number of templates n is 3, threshold $\Gamma = 25$, variance of the particles σ is 25 and the weight α is 0.8. Now, Fig. 7 shows the tracking result.

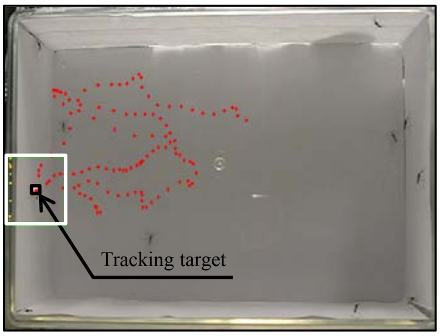

Fig. 7. Tracking result of a mosquito.

It follows from Fig. 7 that it can be tracked corresponding to the irregular motion and velocity change. Moreover, if the object which is detected as candidate which shape similar to a tracking target in search area, we can estimate tracking target position, and distinguish shape similar to a tracking target. Further, we can confirm improve of the tracking accuracy. Fig. 8 shows the trajectory that is estimated by our proposed method and extended Kalman filter. In here, Fig. 8 means the coordinate of the tracking target on the image in each frame. It says that the past method based on Kalman filter degrades the estimated accuracy when tracking target due to change velocity. However, our proposed method can estimate position of the tracking target equal to the estimated position of the true value.

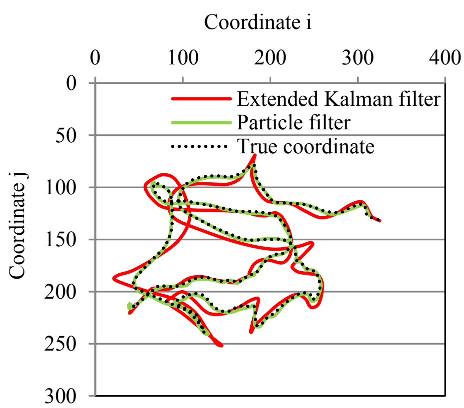

Fig. 8. Trajectory of a mosquito.

5. Conclusion

In this paper, we proposed new tracking method to observe creature such as daphnia, mosquitos and ants. Especially, we considered the tracking method that combined orientation code matching using multiple templates and the particle filter. For multiple templates we adapt the orientation code matching which is robust method to the influence of the illumination change. Therefore, we can detect tracking target in consideration of the past orientation code information. Furthermore, we define likelihood function using orientation code histogram in order to generate the particle filter and estimate the tracking target position In addition, we track the creatures based on evaluation equation which combined similarity by orientation code matching and estimated position using the particle filter. Then, we can distinguish the creatures that shape similar to a tracking target in complicated background. In fact, it follows from experiments of creature tracking that our proposed method is effectiveness. For example, we can track daphnia, mosquito and ant that include complicated background information, nonlinear motion and changing velocity. As a future problem, we need to consider the real time tracking by faster image processing. Further, treating cancer cells, pathogens and microorganisms we find their characterization in medical measurement filed.

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