Luminance Change Independent 3D Snail Tracking

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ABSTRACT

Slow movement of snail can be a benefit since it means less speed of tracking is required to get accurate movement track, but in the other side it is difficult to extract the object because the snail is almost as static as the background. In this paper, we present a technique to track the snail by using one of its common characteristic, dark color of its shell. The technique needs to be robust to illumination change since the experiment is usually to observe the movement of snail both at bright and dim condition. Snail position coordinate in 3D space is calculated using orthogonal stereo vision which combines the information from two images taken from cameras at the top and in front of the aquarium. Experimental results show this technique does not need prior background image extraction and robust to gradual or sudden illumination change.

Keyword
Snail tracking, object tracking, orthogonal stereo vision

Ⅰ. Introduction

There are many experiments using animal to observe their behavior or way of life. The experiment sometimes takes a long time and needs a high accurateness, thus it is difficult and high-cost to use human resource to watch the experiment manually. Computer vision came as one of solutions, by extracting information from image, it helps to observe animal and track their movement automatically, makes animal behavior analysis easier. Some previous works related to animal tracking using computer vision technique including fish tracking [1], insect tracking [2][3], nematode tracking [4], mammal tracking [5] and others.

In this paper, we present snail tracking. Snail moves relatively slow. This can be a benefit where it means less tracking speed required to track the movement accurately, but in the other side, it makes difficult to track the snail by its movement because the snail is almost as static as the background.

Another thing that must be considered in snail tracking is snail different activity in bright and dim condition. Snail is more active in dim condition. Commonly the experiment using snail includes these two conditions. Therefore, snail detection must be insensitive to illumination change.

Tracking technique using differential image of input image and background image which is captured before the experiment failed to be applied here because this technique very susceptible to illumination change. Updating the background image to make it adaptable to illuminance change will be difficult since snail slow movement will turn the object into the background. Here, we used dark color of snail shell as feature to track the snail. This feature is irrelevant to its movement and robust to detect the snail in bright or dim condition. This feature helps to detect snail 2D position in input images, which will be used in the next step. Further description about the method will come forth in section 2.1 to 2.2.

3D coordinate of the snail is obtained using stereo vision, a technique to calculate distance by combining information from images with different viewpoints. Here, the cameras are installed orthogonally to capture front and upper side of the aquarium, so the technique is called orthogonal stereo vision. Detail explanation about this technique will be presented in section 2.3.

The rest of this paper will contain experiment result in section 3, also further discussion and future work in section 4.

Ⅱ. Snail Tracking

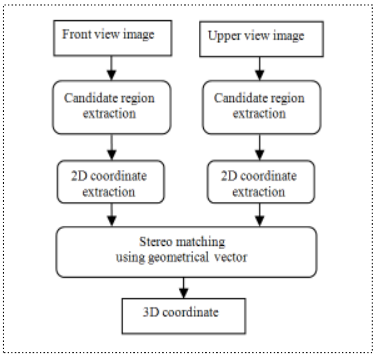

Figure 1. Snail tracking method diagram

The method to track the snail is briefly illustrated in figure 1. Two images are captured from front and upper side of the aquarium. From each image, snail 2D coordinate is extracted which then used in stereo matching process to calculate snail coordinate in 3D space.

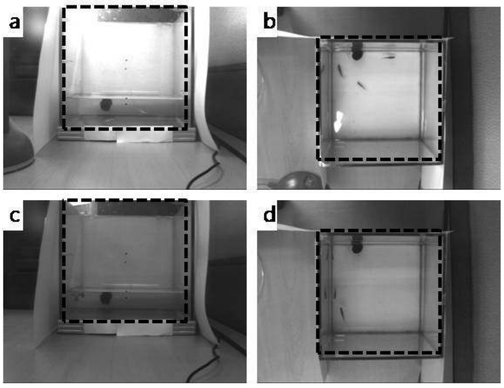

Figure 2. (a) and (b) are front and upper view in bright condition. (c) and (d) are front and upper view in dim condition. Dash squares are input image ROI.

Some conditions that are assumed in the experiment :
- Tracking single snail with dark color of shell.
- There is no darker object in image ROI.
- Snail moves in limited space such as aquarium.
- The experiment including bright and dim condition as shown in figure 2.

1. Extracting snail candidate region

Snail is tracked by its shell dark color. Since we assume there is no other darker object in image ROI, we extract the dark pixels under the cut off value as snail candidate region. The range of darkest pixel is calculated using the equation (1).

$$Cut\ off\ value = \min(I(x,y)) + (\max(I(x,y)) - \min(I(x,y)))*threshold/100 \quad (1)$$

$$Candidate\ region(x,y) \begin{cases} 1 & \text{if } I(x,y) < Cut\ off\ value \\ 0 & otherwise \end{cases} \quad (2)$$

where $I(x,y)$ is the pixels in input image ROI. Threshold is value between 1 and 100, which represent the range of snail region pixel.

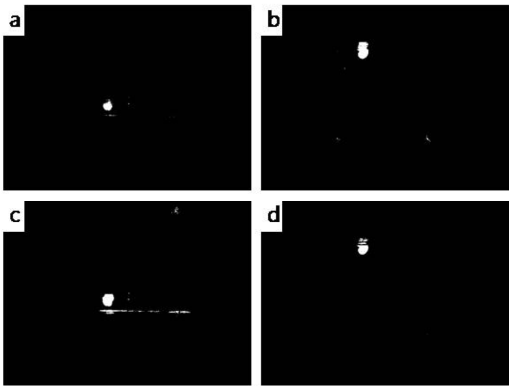

Figure 3. Result of figure 2 after candidate region extraction

The threshold value is set differently for front view image and upper view image because the light which gets into each camera might be different. Figure 3 is the result of figure 2 after candidate region extraction where the threshold value of front view image is set to 6 and threshold value for upper view image is 13. As can be seen in the image, using this method, there is no need to set different threshold value for bright and dim condition during the experiment. The cut off value is automatically change depend on the light condition in the image and the given threshold value.

2. Calculating snail 2D coordinate

When extracting snail candidate region, noise might also extracted as candidate region. This problem can be overcome by using morphological operator such as opening operator. The result illustrated in figure 4.

Snail region then detected by finding the largest block using labeling technique, and the largest block centroid is determined as snail 2D coordinate.

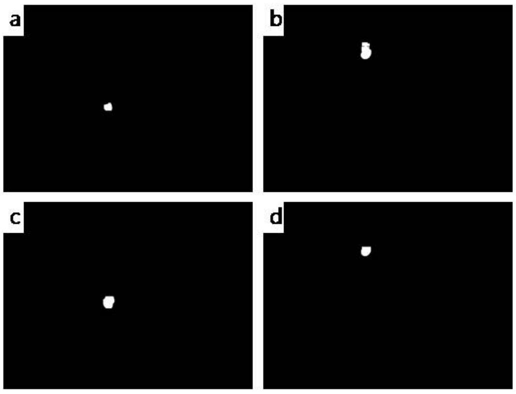

Figure 4. Result of figure 3 after opening operator

3. Calculating snail 3D coordinate

3D coordinates of the snail is calculated using stereo matching technique. In this step, snail 2D coordinates calculated in previous step are combined using geometrical vector technique.

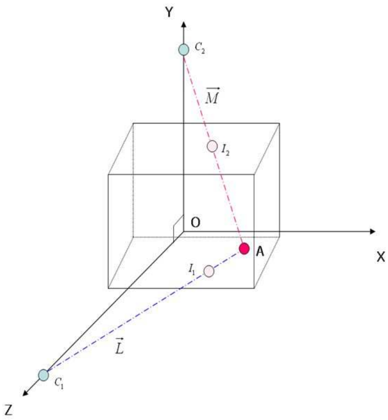

Figure 5. Vector intersection in orthogonal stereo matching

C_1 and C_2 in figure 5 are the position of cameras installed at front and upper side of the aquarium respectively. Both cameras facing the origin point, O. I_1 is object position seen from C_1 camera and I_2 is object position seen from C_2 camera. Object position in 3D space cannot be obtained using image only from one camera, but if we combine the information from these two images by finding intersection of line from C_1 to I_1, $\vec{L}$, and the line from C_2 to I_2, $\vec{M}$, the object position can be predicted. Vector and can be represented as in equation (3) and (4).

$$x = at + \alpha,\ y = bt + \beta,\ z = ct + \gamma \quad (3)$$

$$x = ls + \delta,\ y = ms + \epsilon,\ z = ns + \zeta \quad (4)$$

Here, t and s are parameter for $\vec{L}$ and $\vec{M}$ respectively. $\vec{L}$ value, (a,b,c), is direction vector of I_1-C_1 and $\vec{M}$ value, (l,m,n), is direction vector of I_2-C_2. $(\alpha,\ \beta,\ \gamma)$ is I_1 coordinate and $(\delta,\ \epsilon,\ \zeta)$ is I_2 coordinate.

Intersection point of $\vec{L}$ and $\vec{M}$ can be calculated using equation (5).

$$\begin{aligned} x &= at + \alpha - ls - \delta, \\ y &= bt + \beta - ms - \epsilon, \\ z &= ct + \gamma - ns - \zeta \end{aligned} \quad (5)$$

In this step, there is no guarantee that these two vectors, $\vec{L}$ and $\vec{M}$, will always have an intersection point due to unaccurateness experiment device or error calculation in the previous step. This is can be solved by calculating the shortest line connecting these two vectors, $\vec{N}$, and determine the center of the line as object position. [1] Since $\vec{N}$ is the shortest line connecting $\vec{L}$ and $\vec{M}$, thus N must be orthogonal to $\vec{L}$ and $\vec{M}$. We calculate $\vec{N}$ which satisfy this following condition using equation (6) and (7).

$$\begin{aligned} &\vec{L} \cdot \vec{N} = 0 \\ &t(a^2+b^2+c^2) - s(al+bm+cn) \\ &+ a(\alpha+\delta) + b(\beta-\epsilon) + c(\gamma-\zeta) = 0 \end{aligned} \quad (6)$$

$$\begin{aligned} &\vec{M} \cdot \vec{N} = 0 \\ &t(al+bm+cn) - s(l^2+m^2+n^2) \\ &+ l(\alpha-\delta) + m(\beta-\epsilon) + n(\gamma+\zeta) = 0 \end{aligned} \quad (7)$$

Value of t, s and $\vec{N}$ can be obtain from equation (6) and (7). If we apply these value to equation (3) and equation (4), we can find intersection point between $\vec{L}$ and $\vec{N}$ also $\vec{M}$ and $\vec{N}$. We obtain snail coordinate in 3D space by finding the center point of these two intersection point.

Ⅲ. Experiment using the method

The experiments were done in indoor environment where the light is controlled intentionally. Bright and dim condition will be set by using two lamps, the brighter one and the dimmer one, that are installed to be automatically turned on and off by turns in a specific time using a timer. Here, dimmer lamp is used in dark condition because we cannot detect the snail in dark condition if the lamp is totally turned off.

The cameras and aquarium are fixed as illustrated in figure 5. The method tested by experiment using PC Intel Core Duo 3 GHz 2GB RAM, Visual C++ .NET, Sony Progressive CCD camera, and Matrox Imaging Library. The aquarium size was a cube with edge length 200 mm. The distance of origin point to front camera was 465 mm and upper camera was 625 mm. The experiment showed that this method robust to illumination change and track the snail movement accurately as can be seen in figure 6. Snail coordinate is saved and used for snail behavior analysis. Figure 7 is the example of snail movement in 3D space.

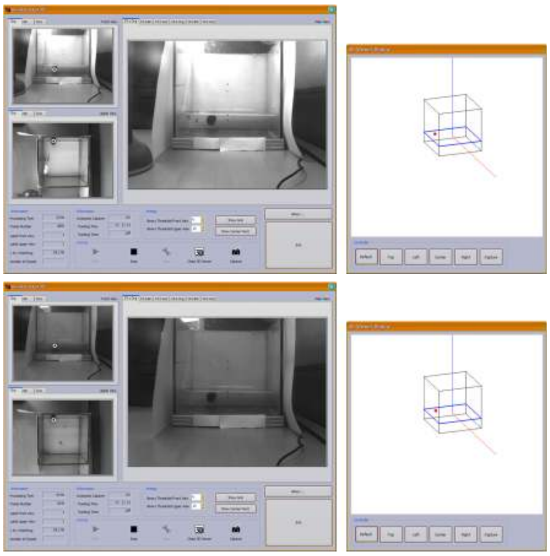

Figure 6. Experiment related to work and its 3D reconstruction. (Top) Bright condition and (bottom) dim condition.

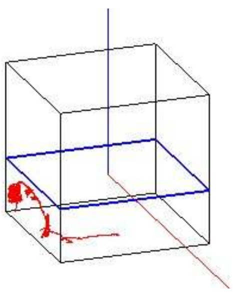

Figure 7. Snail movement during experiment

The problem that sometimes occurred during the experiment was snail reflection which detected as part of snail region as shown in figure 8.

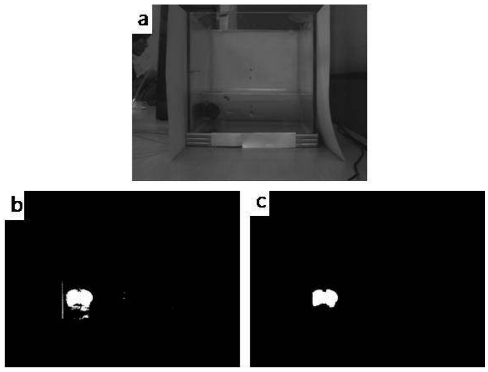

Figure 8. Detection snail reflection as snail region

IV. Conclusion & Future Work

We presented a method to track snail in 3D space using computer vision technique. The feature used in this method is snail dark shell which is robust to detect the snail movement in bright and dim light condition. The method will keep developed to track multiple individual and increase the accurateness by reducing the effect of snail reflection.

References

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