A Neural Network Model for Burrow Surveilance of Fiddler Crabs

Seung-Eun Yu and DaeEun Kim

Biological Cybernetics Lab,
School of Electrical and Electronic Engineering,
Yonsei University, Seoul, Korea
(E-mail: daeeun@yonsei.ac.kr)

Abstract: Fiddler crabs demonstrate burrow surveliance behavior. They defend their burrow against their intruders when the intruders approach their burrow. It seems that crabs can estimate the distance between an intruder and the burrow. In this paper, we analyze the geometry relations among the crab itself, its burrow and an intruder, and derive the trigonometric equation. The retinal position of an intruder, the azimuth and elevation angle depending on the crab-burrow distance can determine the intruder-burrow distance in principle. In this paper, we show a neural network with multilayer perceptrons for the mapping function to determine the intruder-burrow distance. However, our experiments reveal that the distance estimation may be difficult when an intruder approaches the burrow from the opposite side. We suggest that additional information of the intruder image size will be helpful for the distance estimation, or crabs simply determine whether or not the intruder is close to the burrow within some distance rather than estimate the distance accurately.

Keywords: distance estimation, vision, fiddler crab, distance neuron, retinal position

1. INTRODUCTION

Animals use their own sensory systems in various tasks effectively. Foraging insects like bees and desert ants use landmark-based information to return to a target location [2]. The sand scorpions use their tactile senses on their legs to detect insect prey at night without any additional visual or auditory senses [1]. Fiddler crabs are wary of approaching predators or colleagues, and dash back to the burrows in order to protect their nests [9].

It seems that the fiddler crabs can estimate the intruder-burrow distance to a certain extent. The retinal elevation and azimuth angle of the point which a target object contacts with the ground is uniquely determined by the distance between the object and the crab observer [11]. Reversely, the observer can determine the distance of the object. For the burrow surveillance of fiddler crabs, [5], it appears that the fiddler crabs *Uma vomeris* use retinal position information of an intruder to measure the distance between an intruder and the burrow, and respond to protect the nest if the intruder approaches the burrow within some distance.

There have been many neural models involved with distance estimation in animal behaviors, for example, motion detection neurons [4], feature detecting neurons [3], and small moving targets detection neurons [7]. Fiddler crabs might also use neurons with similar characteristics. In this paper, we first analyze the geometric relations with the crab, burrow and an intruder to determine the burrow-intruder distance. A trigonometric equation can be represented with a neural network with multilayer perceptrons. We investigate the role of image size of the intruder for the distance estimation. Instead of estimating the distance accurately, fiddler crabs could respond depending on whether or not the intruder reaches the defense zone of the burrow.

2. DISTANCE ESTIMATION WITH RETINAL POSITION

We first analyze the intruder-burrow distance estimation of the fiddler crabs using the retinal position to defend their nests against an intruder. From the previous works, the fiddler crabs use path integration for the distance L and direction to the burrow [9,10]. In addition, the crabs align their body axis toward the homing direction [9]. From the alignment, the fiddler crabs can estimate the direction α between the burrow and an intruder, using the retinal azimuth angle. Let d_t be the distance between the crab and the intruder. Then with the cosine law, the distance between an intruder and the burrow can be obtained with Eq. (1).

$$d = \sqrt{{d_t}^2 + L^2 - 2d_t L cos(\alpha)} \quad (1)$$

If the retinal position of an intruder is available, the crab can determine the intruder-burrow distance, using simple geometrical computation shown in Equation (2).

$$(x, y) = (h\frac{\sin(\alpha)}{\tan(-\beta)}, h\frac{\cos(\alpha)}{\tan(-\beta)} - L) \quad (2)$$

where L indicates the crab-burrow distance obtained from the path-integration information, h is the height of the crab's eyes from the ground, and for the retinal position, the azimuth and elevation angle of the intruder, are represented as α and β, respectively, and (x, y) is the position of the intruder with respect to the burrow.

The intruder-burrow distance d is the important factor to determine the defense zone for whether the crab will respond or not to run into the burrow for protection. The distance d and the approaching direction ϕ can be obtained with the location given in Eq. (2), which are given below:

$$(d, \phi) = (\sqrt{x^2 + y^2}, \tan^{-1}(\frac{y}{x})) \quad (3)$$

3. SIMULATION AND RESULTS

In this paper, we first compose a visual space inspired by the visual field of the crab. For compound eyes of the fiddler crab [6,8], the number of optic receptors varies depending on the eye regions. In order to observe a target object or an intruder in the flat field efficiently and accurately, the visual space around the horizon has a larger number of visual receptors than the other regions. It means visual information of an intruder with the retinal position can directly map the burrow-intruder distance [5]. We showed that the distance estimation can be obtained by the computation with geometry and trigonometric equations, but the crabs would employ a comparatively simple neuronal network to estimate the distance. Thus, we built a mapping function with multi-layered perceptrons and we used backpropagation learning method for the distance estimation with the retinal view of a target object. Initially, the input parameters are the azimuth and elevation angle of the target as well as the crab-burrow distance. Later, we added the image size information of the intruder for the input parameter. We assume that the crab-burrow distance is estimated with path integration by the crab itself.

The error is smaller when the intruder is approaching from the observer side than the opposite side. If the intruder is at the far region, it is hard to estimate the distance accurately. The burrow surveilance is thus influenced by the approach direction. In the neural network training without the image size information of an intruder, the performance much degrades as seen in in Fig. 1(b). The apparent size information can be helpful to determine the burrow-intruder distance. However, biological experiments [5] show that the burrow surveilance behavior is not influenced by the apparent size of the intruder and it seems the performance does not depend on the approach direction. Possibly the fiddler crabs do not estimate the burrow-intruder distance accurately, but instead they may only check if the intruder is inside the defense zone. It would be an easier task for the fiddler crabs. The above simple approach for navigation can be applied to biomimetic robots modeling the surveilance behavior of fiddler crabs.

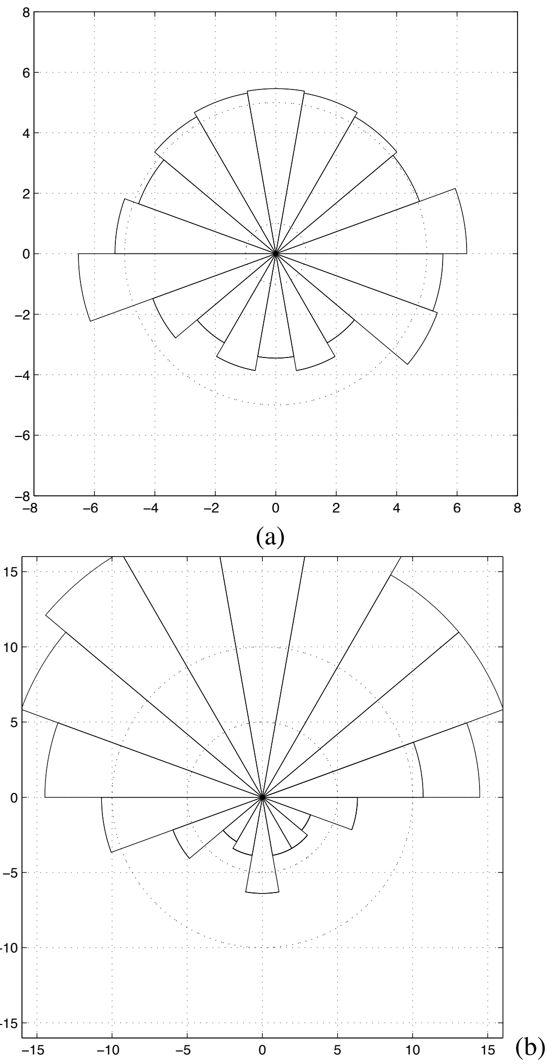

Fig. 1 Error bar representing the amount of error in estimating the distance for each direction when the observer is 30cm away from the burrow (a) image size information is used (b) image size information is not used

Acknowledgments.

This work was supported by the Mid-career Researcher Program through an NRF grant funded by the MEST (No. 2010-0000460)

REFERENCES

[1] P.H. Brownell. Prey detection by the sand scorpion. *Scientific American*, 1984.

[2] BA Cartwright and TS Collett. Landmark learning in bees. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, 151(4):521–543, 1983.

[3] MA Frye and RM Olberg. Visual receptive field properties of feature detecting neurons in the dragonfly. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, 177(5):569–576, 1995.

[4] C. Gilbert and N.J. Strausfeld. The functional organization of male-specific visual neurons in flies. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, 169(4):395–411, 1991.

[5] J.M. Hemmi and J. Zeil. Burrow surveillance in fiddler crabs. II. The sensory cues. *The Journal of experimental biology*, 206(Pt 22):3951, 2003.

[6] M. Land and J. Layne. The visual control of behaviour in fiddler crabs. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, 177(1):91–103, 1995.

[7] K. Nordström and D.C. O'Carroll. Small object detection neurons in female hoverflies. *Proceedings of the Royal Society B: Biological Sciences*, 273(1591):1211, 2006.