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Speed Modulation Mechanism of Insect by Integrating Odor and Wind Sensory Information during Odor Source Localization

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Abstract: When localizing for females or food locations, insects use not only odor but also wind direction information to recognize their environment. In this study, we investigated the effect of wind direction information on insect odor source localization. For this purpose, we built a virtual reality system connected to a virtual environment on a PC, and measured the behavioral changes of insects in response to multisensory inputs. Biological experiments suggest that wind direction information has a significant effect on the localization success rate. We constructed an algorithm that includes this effect, and found that it has a higher localization success rate than conventional algorithms by simulation and robotic experiments.

Keywords: odor source localization, virtual reality system, wind direction information

1. INTRODUCTION

Insects can localize for odor sources and use their abilities to localize for females and feeding grounds. Because odors are distributed discretely as plumes [1], and are carried by the wind, wind direction information has a great influence during odor source localization behavior. Therefore, insects skillfully track odors using wind direction information [2]. In fact, flying insects move upwind when they detect the odor. However, it has not yet quantitatively known how they integrate these sensory information and transform it into behavior. Therefore, in this report, we focus on the female localization behavior of a male silkmoth, *bombyx mori*, and clarify the influence of wind direction information during odor source localization.

In order to investigate the influence of wind direction information, it is necessary to record the timing and direction of odor and wind stimuli which the silkmoth received. In the previous study, the behavior was analyzed using a virtual reality system (VR system) that independently presents odor, wind direction, and visual stimulus and can measure the odor source localization behavior of silkmoth. As a result of comparing the behavior of the silk moth under the conditions of (1) providing the wind stimulus and (2) providing the wind stimulus from the opposite direction of the virtual insect detection direction, there was a significant difference. Comparing the behaviors under these two conditions, it was found that the speed modulation was affected. This modulation depends on the reception frequency of the odor. We constructed an algorithm that switches the velocity modulation according to the wind direction information (Fig.1). By simulation, a highly odor-following effect was obtained [3]. Simulations can represent rectification, but cannot reproduce the complexity of real-world air flow. We will implement the algorithm on a robot and test its effects in a non-rectified environment.

† Mayu Yamada is the presenter of this paper.

2. ROBOT EXPERIMENT

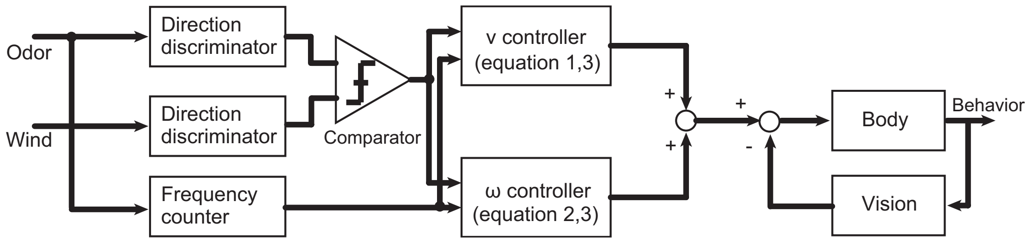
2.1. Experimental conditions

Fig.2 shows the robot used in the experiment. The robot has Omni wheels [4]. The structure of the robot consists of four layers. In the first layer, two alcohol sensors are attached to the front of the robot same as insect antennae. The air is pumped in from behind the sensors by a fan. In the second layer, four airflow sensors are installed at the front, back, left and right sides. The third layer has a microcontroller that can communicate via Bluetooth, and sends commands to the robot and sensor information to the PC. In the fourth layer, red and blue markers are attached, and the trajectory can be calculated by detecting and tracking the markers through image processing of the video taken from above.

Fig.3 shows the experimental environment. As an odor source, $99\,\%$ ethanol is discharged and detected by the alcohol sensor mounted on the robot. A fan blows at $1\,\mathrm{m/s}$ from behind the odor source. The robot starts at a distance of $100\,\mathrm{cm}$ from the goal, and the localization is considered successful when it comes within the radius of the goal of $5\,\mathrm{cm}$. The experiment was recorded by a video camera mounted above.

2.2. Result

The robot experiment results are shown in Fig.4. For comparison, we also experimented with surge-zigzagging algorithm [5] that uses odor information and the casting algorithm [6] that uses odor information and wind direction information. The experiment was performed 20 times for each localization algorithm. The proposed algorithm had the highest success rate. A Fisher's exact test ($p<0.05$) was performed on the success rate, and the results showed that the proposed algorithm had a significantly higher success rate than the Casting localization algorithms.



Source: Elife. Vol. 1 [3]

Fig. 1: Proposed algorithm that modulates speed according to the odor and wind direction information.

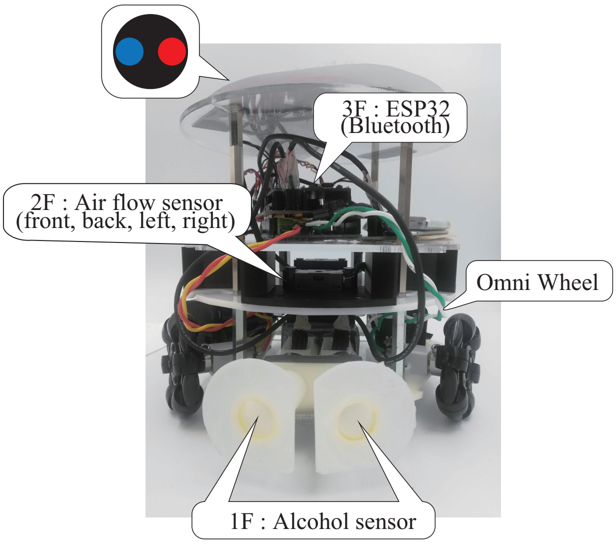


Fig. 2: Omni-wheel robot used in the experiment.

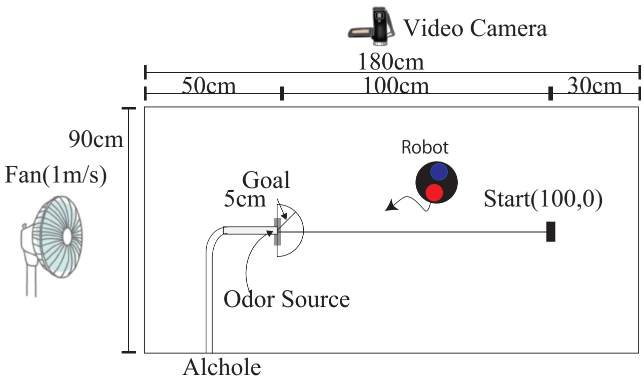


Fig. 3: Experimental condition of robot experiment

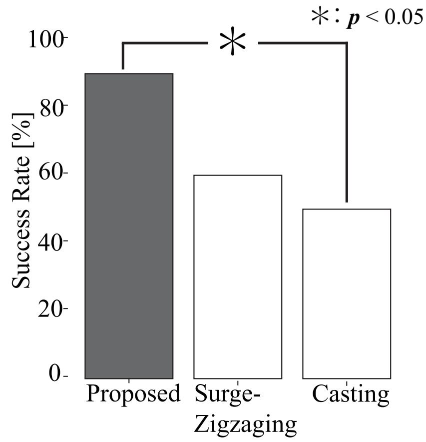


Fig. 4: Success rate of the experiment

3. CONCLUSION

In this study, we conducted robot experiments using odor source localization an algorithm that modulates speed according to the degree of coincidence between odor detection direction and wind direction. As a result, we obtained higher performance than the conventional algorithm. In the future, we will use this algorithm to investigate its effectiveness in complex environments where there are obstacles.

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