Analysis and Modeling of *Diacamma* workers' Behavior

Mai Yuki, Yoshikatsu Hayashi*, Ken Sugawara
Tohoku Gakuin University, 2-1-1, Tenjinzawa, Izumi-ku, Sendai 981-3193 JAPAN
** natural science NPO, 4-7 kitame-cho Aoba-ku, Sendai 980-0023 JAPAN*
(Tel : 81-22-773-3306; Fax : 81-22-773-3306)
(sugawara@cs.tohoku-gakuin.ac.jp)

Abstract: It is well-known that social insects such as ants show interesting collective behaviors. How do they organize such behaviors? To expand understanding of collective behaviors of social insects, we focused on ants, *Diacamma*, and analyzed the behavior of a few individuals. In an experimental set-up, ants are placed in hemisphere without a nest and food and the trajectory of ants is recorded. From this bottom-up approach, we found following characteristics: 1. Activity of individuals increases and decreases periodically. 2. Spontaneous meeting process is observed between two ants and meeting spot of two ants is localized in the experimental field.

Keywords: social insects, ant, meeting process, multi-body dynamics

I. INTRODUCTION

Social insects have some interesting characteristics and show organized group behaviors. Especially, ants' colonies are highly organized and exhibit number of remarkable behaviors. Their colonies consist of numerous individuals and engage in nest construction/ maintenance, taking care of eggs, defending, foraging and so on by well-organized division of labor. These collective behaviors do not require a special individual that controls the behavior of the entire group. Hereditarily homogeneous individuals achieve these collective behaviors by interacting with each other through direct sight or chemical materials, such as pheromones.

Many researchers have been investigating behaviors of ants[1-3] and lots of interesting results have reported. However, not so large number of researches have treated single or some ants' behaviors[4,5]. This means the knowledge of the relationship between the colony-level behaviors and the individual level behaviors is not enough.

We consider the modeling of the behaviors is one of the most effective approaches to combine the individual-level behaviors and colony-level behaviors. Our final goal is to describe ants' behavior as the dynamics of interacting self-driven particles. By treating ants' behaviors from physical viewpoint, we aim to construct a universal model of ants' behaviors. It is also expected to be applied to engineering systems such as muti-robot system[6-8]. In our previous work, we reported a fluctuation of velocity on single ant walk[9]. In their walking, we found the time correlation of walking velocity. From the spectrum of walking velocity, we can see a long-term correlation in the velocity dispersion. We also found the fluctuation is in proportion to the time scale. In spite of long-term correlation in velocity, from the actual value of average velocity and the velocity dispersion, we can regard ants as a random walker.

Then what happens when a few ants is placed in a closed field? It is known that ants from the same colony tend to get together and stay in contact. It means the behavior of a few ants is considerably different from solitary ant. In this paper, we discuss the behaviors of a few ants mainly focusing on a movement of each ant.

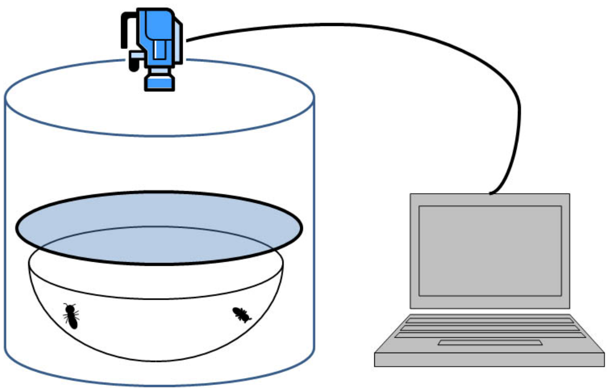

Fig.1: Experimental set up: Ants are released in hemisphere and covered by the clear plate. Trajectory of ants is recorded by CCD camera.

II. METHODS AND ANALYSIS

We observed the behaviors of *Diacamma*, which lives in Okinawa and several islands. In our experiment, one to several ants are randomly picked up and placed in acrylic hemisphere (30cm in diameter) field. The hemisphere is covered by a transparent acrylic board during the experiment. CCD camera is equipped at the top of the experimental equipment, which size is 40cm x 40cm x 90cm height(Fig.1). Trajectory of ants walking in hemisphere is recorded and we analyze the trajectory of ants as a function of time.

III. RESULTS AND DISCUSSION

1. Analysis of trajectory of single to multi ants

Firstly, we measured the trajectory of single ant. During the first 30 minutes, the trajectory of ants spreads in the field. The space distribution of the trajectory, however, becomes localized after 30 minutes.

Next, we measured the trajectory of two ants. As time proceeds, they walk less and less and eventually halt at one place. Space distribution of ant position is localized as well.

To further investigate the walking distance more quantit atively, we analyzed the walking distance of single ant s ummed up in every 10 minutes. Walking distance gradu ally decreases and eventually becomes inactive at 120 minutes. The walking distance can be interpreted as acti vity of ant. After 120minutes, it shows that single ant re peats active and inactive role. Further result shows that t he activity of single ant changes periodically. This indic ates that the single ant has some rhythmic component in its activity.

In the case of two ants placed in hemisphere, we suggest that there should be two stages in ants' behavior from the result of walking distance.

(1)At former stage, the difference of walking distance between two ants is small (Fig.2), thus, both of two ants are active, i.e., they travel around the surface of hemisphere. 60 minutes later, both of them become inactive. Compared with trajectory of two ants, it is considered that they finish exploring the unknown environment within 90 minutes.

(2)At latter stage, the difference of walking distance bet ween two ants becomes larger, thus, one of them becom es inactive. There seems to be an exchange of active and inactive role between two ants..

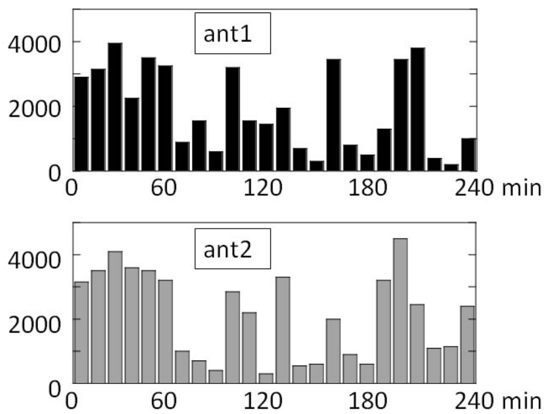

Fig.2: Walking distance of two ants summed in every 10 minutes as a function of time: Red column denotes ant A, and blue column denotes ant B.

2. Analysis of meeting spot of ants' behaviors

By the observation of two ants' behavior, a few meeting spot of two ants appear in the experimental field (Fig.3). We suggest that one or some chemicals affect to organize the spots, and build a simple model to investigate the mechanism of emergence of meeting spot.

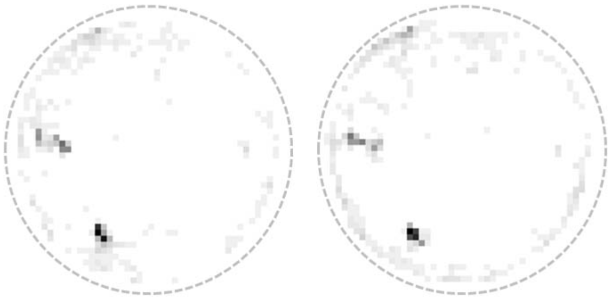

Fig.3. Existing rate of ant 1 (left) and ant 2 (right). Degree of darkness is in proportion to the rate.

ACKNOWLEDGEMENT

This work is partially supported by a Grant-in-Aid for Scientific Research on Priority Areas "Emergence of Adaptive Motor Function through Interaction between Body, Brain and Environment" from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

REFERENCES

[1] Hölldobler B, Wilson EO (1990), The Ants. Harvard University Press.

[2] Hölldobler B, Wilson EO (1995), Journey to the Ants: A Story of Scientific Exploration, Harvard University Press.

[3] Gordon D (2000), Ants at Work, W W Norton & Co Inc.

[4] Cole BJ (1992), Short-term activity cycles in ants. Behav. Ecol. Sociobiol. 31:181-187.

[5] Cole BJ, Cheshire D (1996), Mobile Cellular Automata Models of Ant Behavior. Am. Naturalist 148: 1-15.

[6] Bonabeau E, Theraulaz G, Dorigo M (1999), Swarm Intelligence: From Natural to Artificial Systems, Oxford Univ Press.

[7] Krieger MJB, Billeter JB, Keller L (2000), Ant-like task allocation and recruitment in cooperative robots. Nature 406:992-995.

[8] Balch T, Parker LE (2002), Robot Teams: From Diversity to Polymorphism, A K Peters Ltd.

[9] Uchikawa T, Sugawara K, Kikuchi T, Tsuji K and Hayakawa Y (2007), Time-series analysis of ant behavior and its modeling (in Japanese). IEICE tech. report. Nonlinear problems, 106(573) 20070226 : 27-30.

