Modeling of Patrol Behavior of *Diacamma*'s Gamergate

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Abstract: Gamergate (generally called "queen") of *Diacamma sp.* walks around in the nest and comes in contact with the workers. The gamergate informs its presence to the workers by the physical contact. This behavior is called "patrol." In previous works, it is reported the gamergate controls the patrolling time depending on the colony size. How does the gamergate know the colony size and control the patrolling time? In this paper, we propose a simple dynamics to explain this behavior. We assume the gamergate and the workers have internal state which interacts by physical contacts. By numerical simulations, we confirm the patrol time of the proposed model depends on the size of colony.

Keywords: *Diacamma sp*, gamergate, patrol behavior, modeling

I. INTRODUCTION

It is well-known that ants' colonies are highly organized and exhibit number of remarkable behaviors. Their colonies consist of numerous individuals and each individual engages in nest construction/maintenance, defending, foraging, taking care of eggs and so on.

In the colony of *Diacamma sp*, which lives in Okinawa and several islands, the gamergate (generally called "queen") randomly repeats walking and quiescence in the nest and comes in contact with workers. This behavior is called "patrol." The aim of patrol is considered to rule its colony.

In previous works, following facts have been reported[1-5]:

(1) The gamergate walks around in the nest and comes in contact with the workers.

(2) Each worker has an egg production performance, but it is inhibited when the gamergate exists in the nest.

(3) Presence of the gamergate is detected by physical contact between the gamergate and the worker.

(4) The gamergate transfers the information about its presence by chemical signals.

(5) When the gamergate disappears from the nest, each worker starts to lay eggs 3 to 6 hours later.

(6) The gamergate can detect the condition of worker's ovary.

It was also reported that the gamergate increases the number of patrolling time as the colony grows. It seems the gamergate knows the size of its colony. How does the gamergate know the colony size and control the patrolling time? In this paper, we propose a simple model to explain the mechanism of colony size dependent patrolling behavior by introducing internal state which interacts by physical contacts.

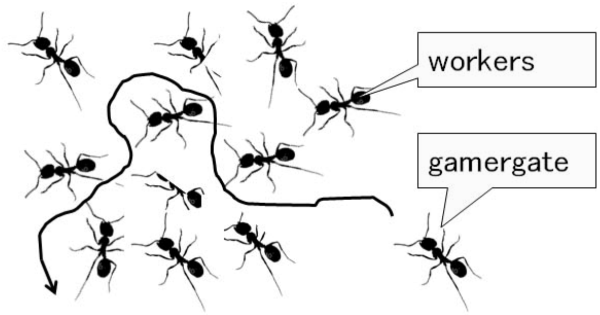

Fig.1. Patrolling behavior of *Diacamma* in the nest.

II. MODELING OF PATROL BEHAVIOR

From experimental results, it is natural to introduce an internal state for each individual. We assume the gamergate has an internal state I_g which controls patrolling behavior, and each worker has an internal state I_{wi} which implies the condition of ovary. Based on the facts described in previous section, we consider I_g is increased by the internal value of i-th worker, which the gamergate contacts.

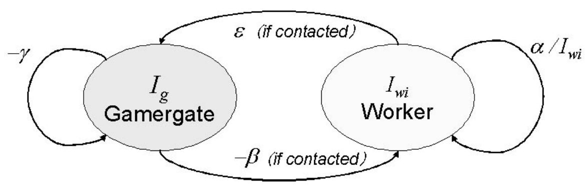

Fig.2. Diagram of proposed model

As the egg production performance of each worker is inhibited by the physical contact, we assume the internal value of the worker decreases when it encounters the gamergate. Fig.2 shows the interaction of I_g and I_{wi}, and the dynamics of the system is described as follows:

$$\begin{aligned} \dot{I}_g &= -\gamma \cdot I_g + \varepsilon \cdot \delta(\vec{x}_g - \vec{x}_{w_i}) \cdot I_{w_i} \\ \dot{I}_{w_i} &= \alpha / I_{w_i} - \beta \cdot \delta(\vec{x}_{w_i} - \vec{x}_g) \cdot I_{w_i}, \end{aligned} \tag{1}$$

where x_g, x_{wi} denote the position of the gamergate and the worker i, respectively. $\alpha, \beta, \varepsilon, \gamma$ are constant. $\delta(r)$ denotes delta function.
We assume quiescence time τ_q and walking time τ_w of the gamergate depend on the probability as follows:

$$\begin{aligned} \tau_q &= \langle C_0 \cdot I_g \rangle \\ \tau_w &= \langle C_1 \rangle \end{aligned} \tag{2}$$

where C_0 and C_1 are constant.

III. RESULTS AND DISCUSSION

In this section, we show the results obtained by numerical simulation. Fig.3 shows distribution of walking time of the gamergate in case of colony size N=70. Here the mean and SD are 83.6 and 82.9. Experimental result in case of N=75 shows those are 81.1 and 70.9[5]. We obtained similar results in case of other colony sizes.

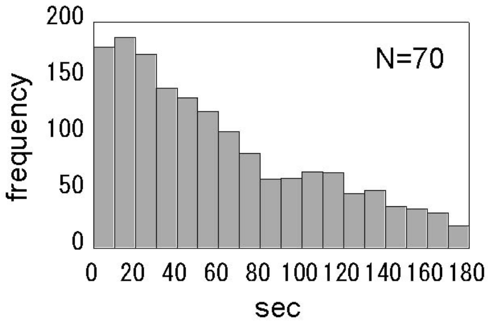

Fig.3. Frequency of walking duration of gamergate.

Fig.4 shows the total patrol time and total number of patrolling. Horizontal axis is the colony size, bar graph expresses the total patrolling time, and dots are the total number of patrolling behavior. This figure shows the activity for patrolling is in proportion to the colony size as observed in the experiment. We can conclude proposed model describes the characteristics of *Diacamma*'s behaviors qualitatively.

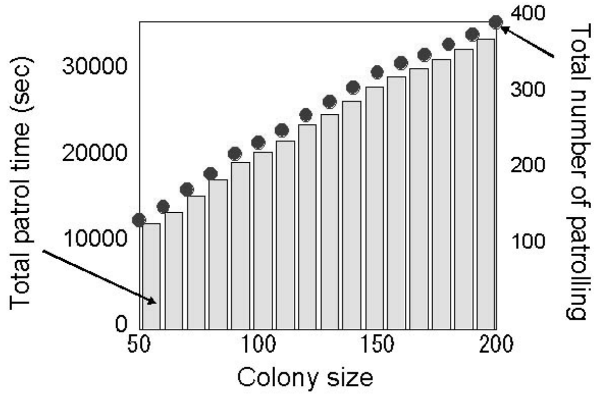

Fig.4. Total patrol time and total number of patrolling.

We are considering the behavior of the gamergate in *Diacamma*'s colony is applicable to multi-robot system. One of the possible applications is a cooperative mining system, in which small robots as "the worker" engage in mining and a large robot irregularly moves around the field and collects the material from the worker robots. Now we are designing and evaluating this type of mining system.

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