One approach to implicit observer: estimation of subpopulations in foraging by ants-like colony

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1 Introduction

In swarm systems, it has a great meaning for an individual to know states of a whole group, e.g., how many agents engage in the same work or attend to different works. This paper is motivated by insect phenomena: ants or termites exhibit adaptive behaviors in the real world, such as: role division, environment adaptability, nevertheless they have physically tiny brains with limited deduction capacity [1,2]. These phenomena have been attracting control engineers as well as biologists to motivate them to make a great deal of effort.

Our research [3] focuses on the foraging task – searching the field for food sources, transporting the food packets to the nest. One of our previous results indicated the importance of two types of ants, what we call the hard-working ants and the lazy ants: the hard-working ants execute an action by pursuing pheromones and the lazy ants always move around the field depositing the pheromones. We conduct statistical analyses to show that moderate existence of the lazy ants would boost efficient food transportation; in particular, we point out that the lazy ants play as explorer of newly emerged food sources. However, the ratio of random ants should change with respect to the sum of food packets in each source and the distribution of multiple food sources.

In this work, we propose to tackle this problem by using a distributed estimation of the global ratio of the two types of ants, with the goal of automatically switching the types of ants from one type to another based on environmental conditions. If an individual knows the ratio of subpopulations in the colony, the efficient food transportation will be autonomously conducted because it can estimate the subpopulations in the colony based on local sensing information; the sum of oriented ants and the sum of random ants. This type of estimation may be defined as the *Implicit Observer* because each agent does not use the group model *directly*.

After designing the model of ants foraging based on oriented ants and random ants, we examine the estimation accuracy based on the personal experience of which types of ants have been encountered. The point we wish to emphasize here is that each ant tries to estimate the global mixture ratio based only on its memorized history. Thus, we analyze it by changing the memory duration and the perceived area of the ants.

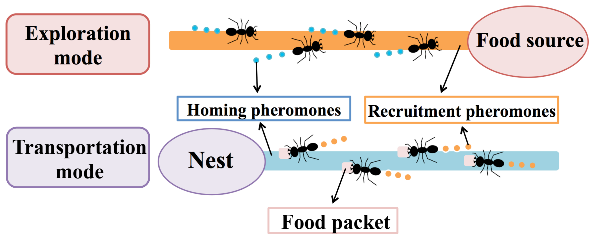


Figure 1: Modeling of switching between exploration and transportation modes in the ants foraging.

2 Foraging model

Let us begin with building a model of foraging task by ant-like colony. Each ant is supposed to possess two modes: *exploration* and *transportation*, and switches these two modes dynamically as shown in Fig. 1. The duration from leaving their nests to reaching food sources is called *exploration mode*. On contrast, the duration returning from the food source to their nest is called *transportation mode*. Ants deposit and perceive two types of pheromones (recruitment/homing pheromones). Both pheromones are volatile, which means they evaporate from the field and diffuse into space as a function of time, with reference to [4]. The detailed explanation about the equations of evaporation and diffusion are written in our previous work [5].

In addition to the two modes, we use two types of ants, called *oriented* and *random* ants. Oriented ants pursue the pheromones along the pheromone concentration. Random ants always move *randomly* depositing the pheromones. An ant tries to take a rest at a constant probability. Both of ants are designed to memorize the history of own encountered experience in each step as shows in Fig. 2; they are supposed to keep a history within its memory length (duration) and update the newest one by releasing the oldest one. We compare the estimation accuracy calculated from the oriented ants' history and that of the random ants history by changing the memory length and the perceived region r.

3 Analysis of Implicit Observer

We conduct foraging simulations on the cellular space, in which 3 food sources are placed on the radial direction from the nest positioned on the center. Total ants are set to 100; the oriented ants are 70 and the random ants are 30.

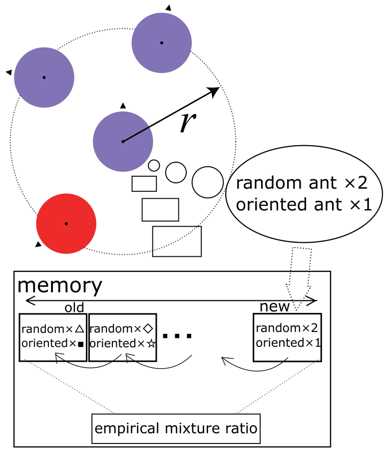


Figure 2: Schematic explanation of ants' memory; a blue agent memorizes the sum of oriented ants and that of random ants in each step

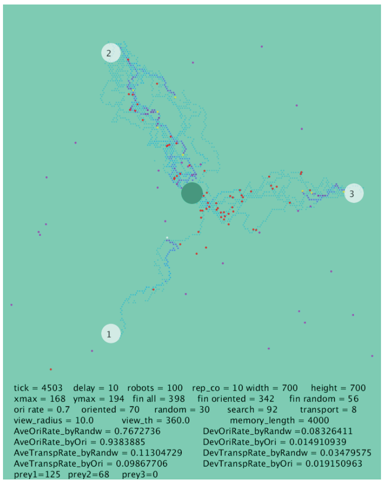
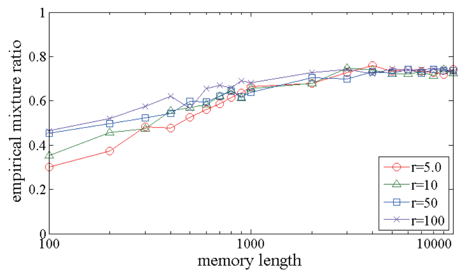
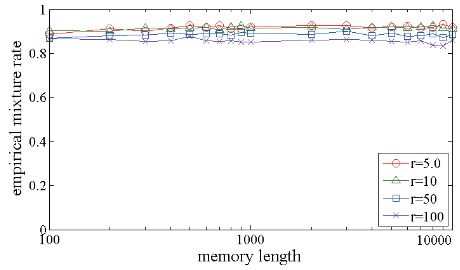


Figure 3: Simulation snapshot; the foraging is conduceted on the cellular space by placing 3 food sources. the purple color cell expresses the pheromone concentration and the red color cell expresses the ant agents

Of course, every ant does not know *true* mixture ratio. The example of foraging behaviors is illustrated in Fig. 3. In the foraging, we analyze the estimation accuracy by changing the vision radius r and the memory duration (length). Fig. 4(a) shows the empirical mixture ratio of oriented ants estimated from random ants' view. Empirical mixture ratio means that the ratio is calculated based on the personal experience of which type of ants have been encountered. Besides Fig. 4(b) shows that from oriented ants' view. Via the analyses, we found that the random ants accurately estimate the mixture ratio of oriented ants, while the oriented ants cannot estimate it. The reason is the exploration role of the random ants; the random ant explores the field due to walking around the field, while the oriented ants mainly positions on the generalized pheromone route from the nest to the food sources. The exploration role of random ants will help to estimate the global (true) mixture ratio.



(a) Average of the empirical mixture ratio calculated based on random ants' history



(b) Average of the empirical mixture ratio calculated based on oriented ants' history

Figure 4: Total ants is 100 (True mixture ratio = 0.7)

4 Conclusion

This paper discussed the foraging behaviors of ants-like agents, especially in distributed estimating of subpopulations in the colony. Based on the proposed idea, what we call the *Implicit Observer*, we challenge to estimate the global mixture ratio based on the personal experience of which type of ants have been encountered. Via numerical simulations, we can say that the random ants estimate the proportion of oriented ants by appropriate settings of memory length. Future works will concentrate on the effect of sensing area and the length of memory length in detail.

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