The Fourteenth International Symposium on Artificial Life and Robotics 2009 (AROB 14th '09),
B-Con Plaza, Beppu, Oita, Japan, February 5 - 7, 2009

Development of a Desktop Swarm Robot System based on Pheromone Communication

Naoyuki Kitamura
Advanced Course of Electricity and Control System Engineering
Anan National College of Technology
265 Aoki Minobayashi,
Anan, Tokushima 774-0017, Japan
kitamura@emergence.jp

Yoshiyuki Nakamichi
Department of Systems and Control Engineering
Anan National College of Technology
265 Aoki Minobayashi,
Anan, Tokushima 774-0017, Japan
nakamiti@emergence.jp

Koji Fukuda
Department of Electronic Control Engineering
Gifu National College of Technology
2236-2 Kamimakuwa, Motosu,
Gifu 501-0495, Japan
fukuda@gifu-nct.ac.jp

Abstract

Complex and adaptive behavior of population emerges in social insects. Especially in ants, pheromone communication is the key to understanding their swarm intelligence. This paper proposes a swarm robot system based on pheromone communication and reports our current status of development of the robot system. We believe that the system could be used in swarm robotics and complex systems education.

Key words: multi robot system, pheromone communication, swarm intelligence

1 Introduction

Complex and adaptive behavior of population emerges in social insects. Especially in ants, pheromone communication is the key to understanding their swarm intelligence. The study of mechanisms of pheromone communication and its technological and/or educational application are highlighted in recent year. This paper proposes a desktop swarm robot system based on pheromone communication and reports our current status of development of the robot system. We believe that the system could be used in swarm robotics and complex systems education.

2 Backgrounds

One of main features of pheromone communication is that pheromone di use and evaporate, so its communication media is variable with time. To realize the feature in real robot systems is important for emergence of ant-like swarm intelligence. However it is difficult to treat features of pheromone by using chemical materials in real robot systems.

In past studies, some robot systems based on pheromone communication are using virtual pheromone instead of chemical materials.

For example, Payton proposed "Pheromone Robotics," in which virtual pheromone is expressed by wireless infrared technology [1]. Sugawara conducted ant-like foraging experiments using "V-DEAR" which is composed of the LC projector, the CCD camera and autonomous mobile robots equipped with color sensors [2, 3]. In this system, virtual pheromones were replaced with graphics projected on the ground.

3 A desktop swarm robot system based on pheromone communication

3.1 Concept

One of the goals of our study is development of swarm robot system for educational use. So, the robots should behave on desktop and virtual pheromone should be observable for students. We propose a desktop swarm robot system based on pheromone communication using pen display (Figure 1).

Main components of our system are a pen display and small robots. The pen display shows virtual pheromone, a nest and food resources, and monitors robots' actions. The small robots have color sensors and a pen. The color sensors detect virtual pheromone, nest and food resources shown as graphics on display. The pen of display is used for secreting virtual pheromone.

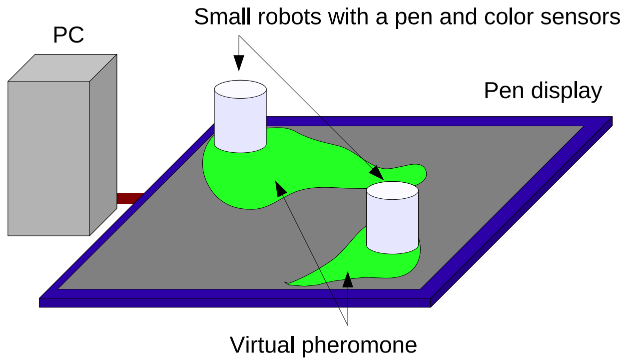


Figure 1: The concept of desktop swarm robot system based on pheromone communication.

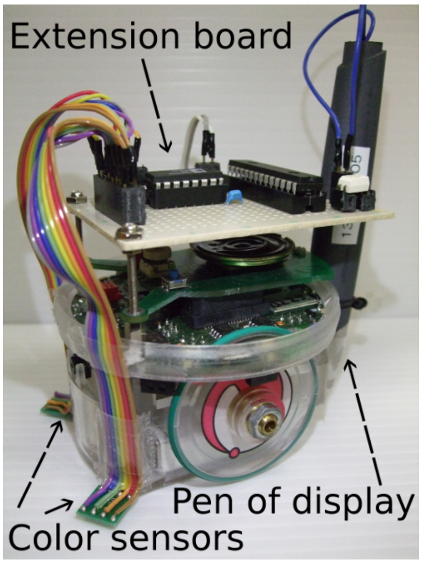


Figure 2: The e-Puck connected with color sensors and a pen of display via extention board.

3.2 Robots

In this study, the e-Puck [4] was adopted as small robot. Two color sensors for detecting colors from display and one pen of display for secreating pheromone were connected to the robot via extension board (Figure 2).

3.3 Pheromone

The 21 inch pen display (Cintiq 21UX) displays virtual pheromone, nest and food as colors on $X \quad Y$ grid like [5, 6].

The robots were able to secrete several types of pheromones at the same point in the environment. However only a pheromone type which is more secreted is displayed on screen.

In the following, the type of pheromone is identi ed by the subscript v ($v = 1, 2, \quad$). Each robot was capable of depositing pheromones, which subsequently gradually evaporated and di used. The pen display displayes only di using pheromone.

In the following, deposited pheromone and di using pheromone are represented by $T_v(x,y)$ and $P_v(x,y)$, respectively, where $T_v(x,y)$ is the intensity of deposited pheromone at position (x,y) and $P_v(x,y)$ is the intensity of di using pheromone at position (x,y). The di usion process was de ned by a partial di erential equation as follows:

$$T_v(x,y) = (1 \quad {}_{eva})T_v(x,y) + \sum_{k=1}^{N_a} \Delta T_v^k(x,y) \tag{1}$$

$$\Delta T_v^k(x,y) = \begin{cases} Q_p & \text{if } k\text{-th ant agent on the grid } (x,y) \text{ put the pheromone } v \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$P_v(x,y) = P_v(x,y) + {}_{dif}(P_v(x \quad 1,y) + P_v(x,y+1) + P_v(x,y \quad 1) + P_v(x+1,y) \quad 5P_v(x,y)) + {}_{eva}T_v(x,y) \tag{3}$$

where the parameters ${}_{eva}$ and ${}_{dif}$ are the evaporation rate and the di usion rate of the pheromone per unit time, respectively. The superscript asterisk, "*", denotes the intensity of pheromone at after 200ms, and Q_p is the intensity of the pheromone deposited by a robot.

4 Experiments

Using this system, we conducted the experiments to simulate foraging behaviors of ants. For comparison, we conducted the experiments with robots which was not using pen of display.

4.1 Setting

The robots' behaviors were designed as follows. The robots could secrete two types of pheromone which are "food pheromone" and "nest pheromone". The food pheromone, which was deposited by robots on encountering a food resource, indicated the presence of food resources. If robots without food detected this pheromone, they moved along its gradient towards higher pheromone concentrations. The nest pheromone indicated the location of the nest. If robots were in the nest, they deposited this pheromone. If robots that carried food resources detected this pheromone, they moved along its gradient towards higher pheromone concentrations. Figure 3 is the state chart of this behavior.

Table 1 shows meanings of displayed colors. These were distinguishable colors for color sensors in preliminary experiment.

Table 1: Meanings of displayed colors.

Color name	R	G	B	Meaning
White	255	255	255	Nest
Green	34	177	76	Food
Orange	255	126	0	Nest pheromone
Purplish red	153	0	48	Food pheromone
Black	0	0	0	(nothing)

Details of the parameter settings are given in Table 2.

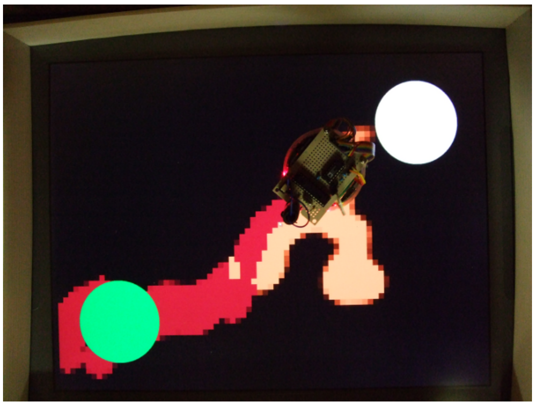
4.2 Results

Figure 4 shows snapshots of experiments.

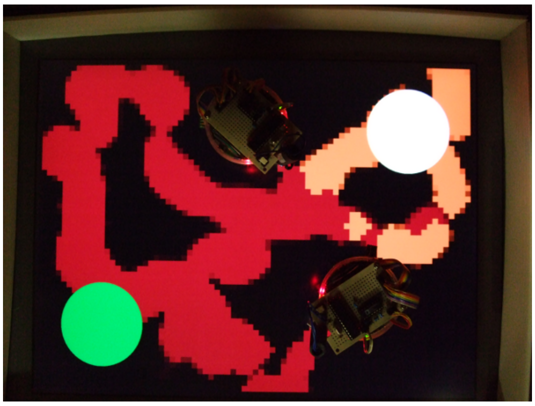
Table 3 shows average number of times that arrived at the destination (food or nest) per one robot for 15 minutes. One of nding clearly demonstrates the emergence of a pheromone communication that increased the efficiency of foraging in the case of using pheromone. The other is that the efficiency of foraging did not increase with the number of robots because robots obstructed the path of each other and/or pheromone trails were not established.

Table 2: Parameter settings.

X	Y	eva	dif	Q_p
80	60	0.01	0.01	100,000



(a) Experiment with one robot.



(b) Experiment with two robots.

Figure 4: Snapshots of experiments.

Table 3: Average number of times that arrived at the destination (food or nest) per one robot for 15 minutes.

Number of robots	Pheromone (Pen)	
	Use	Not use
1	25.0	10.0
2	16.5	11.5

5 Conclusion

This paper describes a desktop swarm robot system based on pheromone communication. Using this system, we conducted experiments like ant foraging. In the future works, we will propose using in complex systems education.

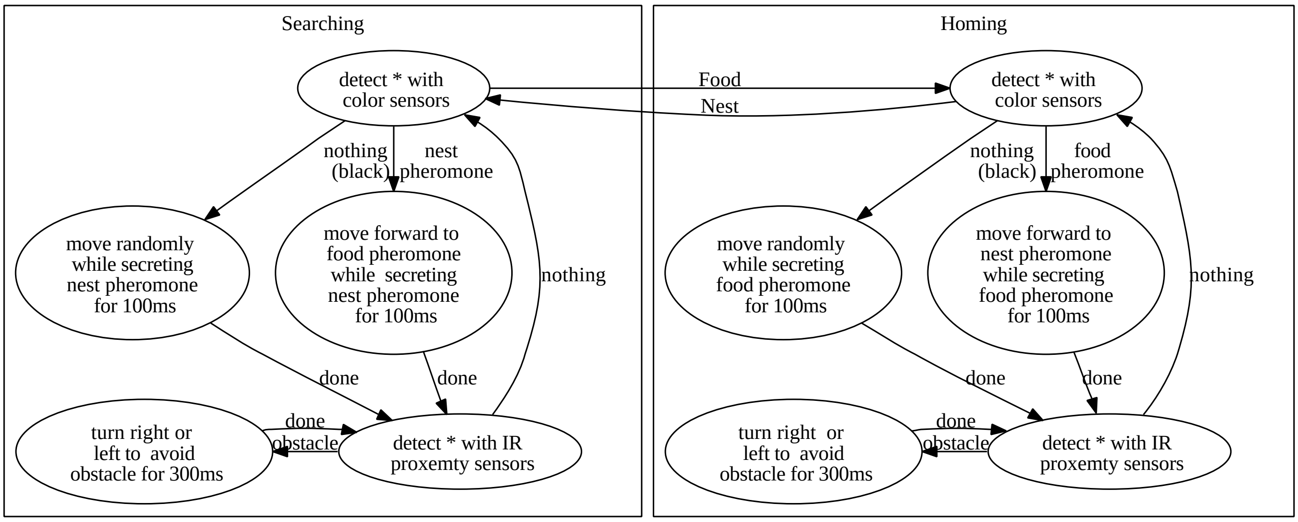


Figure 3: The state chart of robot's behavior.

Acknowledgments

This work was supported by KAKENHI (19700227).

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