# Pattern Formation Using Multiple Robots


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***Abstract*—Pattern formation is one of typical problems in the field of multi-robot cooperation. It can be applied to complex application scenarios such as region coverage and path exploration. Compare to traditional multi-robot coordination algorithm, the method based on swarm robots to solve the issue of pattern formation has better scalability and dynamic adaptability and robustness. In this demo, we propose a scalable algorithm using a modified gradient descent technique which allows a swarm of robots to form a letter, such as 'A'. In this demo, we verify our algorithm through experimentation in a team of self-organized robots, in which communication with each other is through Zigbee network.**



***Keywords--Pattern Formation;Swarm Robots***


## I. INTRODUCTION

The research on the algorithm based on swarm robots to solve the issue of pattern formation has important practical and scientific significance. For example, in military reconnaissance, the robotic nodes will be dropped onto the battle field from a plane and land at random positions, the robots will be expected to arrange themselves into a predetermined formation in order to perform a specific task [1]. Also, algorithm of pattern formation can be applied to other complex application scenarios such as path exploration [2] and target search [3]. Furthermore, the research process of pattern formation is involved with many problems such as task allocation, self-organization and dynamic optimization in multi-robot cooperation which also have research value.

Recent advances in pattern formation have made many meaningful achievements. The Lab of GRASP in University of Pennsylvania involve in the swarms project[4], they proposed a algorithm applied to pattern formation: first, the specified pattern is generated by interpolated implicit function[5], then the robots gather on that pattern, at last , robots scatter along the pattern. In addition, GRASP also proposed a new method called market-based coordination protocols [6] to resolve problem of task allocation in multi-robot pattern formation. Intelligent Control Laboratory in Peking University studied the pattern formation of geometry [7], they establish a mathematical model of pattern formation through "global repulsive force" and "selective attraction" among the individuals. Eventually they use this mathematical model to construct a variety of symmetrical or non-symmetric pattern.

In this demo, different from previous research work, we present an approach that allows a swarm of robots to form patterns by using a modified gradient descent technique to solve the problem of location and repulsive force to enhance the robustness of swarm robots system. Our demo runs on a grid map, and we specify each grid with different height grads so that the self-organized and error-resistant control of distributed autonomous robots could search map simultaneously and find their respective target points (a random process) using a modified gradient descent technique[8,9]. At the same time, According to the different repulsive force, robots can automatically adjust the relative position of each other, and such method could make the group with good robustness performance [10]. We illustrate our approach of pattern formation through real experiments using a group of robots.

## II. DEMO DESCRIPTIONS

In this demo, we use 10 homogeneous robots to form a letter of 'A', furthermore, we will show the formation can be continued even if some of the robots break down or they encounter obstacles [11].

Following scenarios can describe the specific principles of our demo.

### A. *Scenario1:Environment without barrier*

PC terminal sends a message to each robot and tells them what specific shape they are going to form. Then the message channel between PC and the robotic group is closed. No

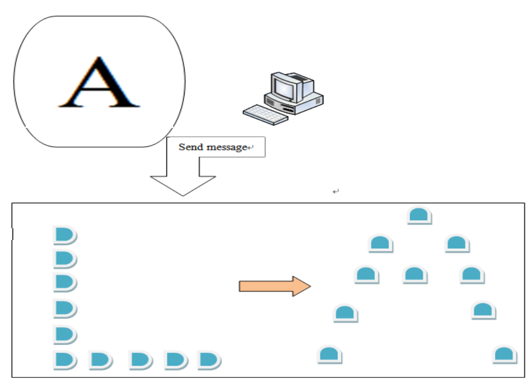


Figure 1. environment without barrier


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additional information is needed. Robots with that message will start to perform their formation work. They will find a global optimization way to complete the formation work according to our algorithm.

### B. *Scenario2:Environment barrier*

Several barriers with different shapes and positions are added randomly. Robots could identify these barriers, walk aside of them and still finish the pattern formation. As before, no further information is needed from the outside system.

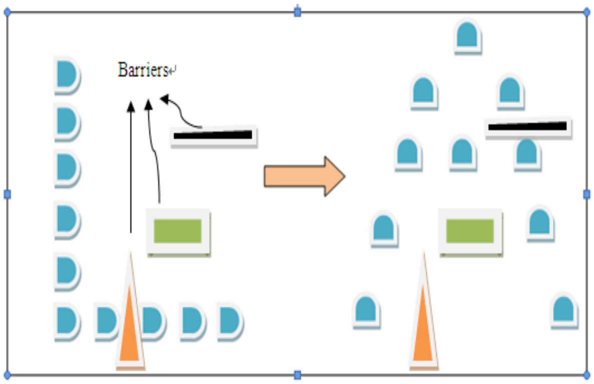


Figure 2. pattern formation with barriers

### C. *Scenario3: Self-organized Robustness*

We set this situations to show whether if the self-organized robotic group could be robustness while missing one or several robots, or in the situation that more robots are added. Form the Fig. 3, we can see that two robots are broken, but new robots added, and our robotic group could still do the same formation work with only local communication among each other.

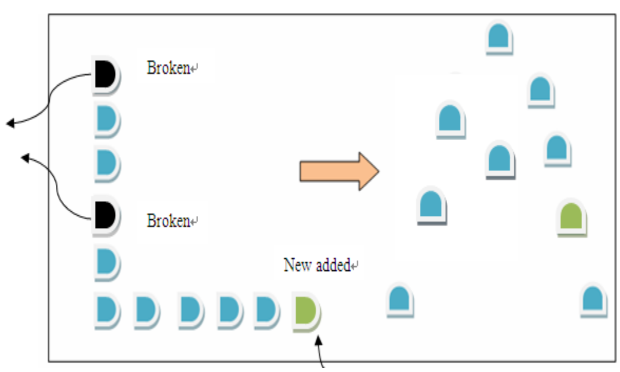


Figure 3. Self-organized Robustness

## III. EXPERIMENTAL ENVIRONMENTS

In this part, we will introduce the experimental environments, including experimental scene, PC terminal, the robot used in this demo and how they communicate with each other. At last, our requirements to the demo organizer are also given.

### A. *Experimental scence*

Fig. 4 shows the formation scene. In a designated region, we format letter 'A', and we also set up obstacles which can be detected by the robots via IR probe to increase the difficulty of pattern formation. The specific locations of these coordinates and barriers in the designated region are unknown to the robots, and it needs robots to discover them during the process of pattern formation.

Figure 4. experimental scence

### B. *Communication*

The multi-robot system is essentially a mobile Wireless Sensor Network (WSN). Robots communicate with each other via Zigbee protocol. The network of the robots is self-organized and dynamic. In a Zigbee network, there are two type of nodes: end device node and coordinator node. Each robot is an end device type node, and the terminal acts as a coordinator node.

### C. *Robot*

Fig. 5 shows the robots used in the demonstration. They are limited intelligent robots (as simple as possible) which communicate with each other via Zigbee network. The control chip of the robot is LM3S1968 by Luminary Micro. Each robot is driven by a pair of step-motor, and can detect the environment by five infrared detector distributed around the

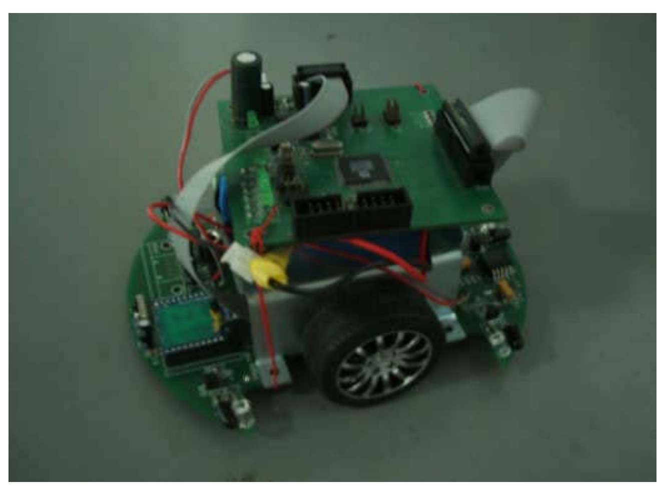

Figure 5. Robot

robot. An Xbee ZNet 2.5 RF module is used for communication. The robot is powered by a battery. There are also some free interfaces for other peripherals which may be adopted in the future.

### D. Teminal

The terminal is a PC which sends the "start" signal to the robots, when robots receive the signal, they begin to start their formation task and the terminal doesn't send messages any more to help formation during the process of pattern formation, so if the terminal is turned off, the robots can still form the letter of 'A'.

The program is running on Windows XP operating system and it needs serial port support provided by the PC.

**These are several notes for the demo organizer.**

**1 Space needed: 2.5×2.5 meter space;**

**2 Light condition: low-light;**

**3 A computer with serial port, with windows XP operating system;**

**4 Set time required: one hour;**

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