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# Gradual spatial pattern formation of homogeneous robot group

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**Abstract**

This paper proposes a gradual formation of a spatial pattern for a homogeneous robot group. The autonomous formation of spatial pattern is one of key technologies for the advancement of cooperative robotic systems because a pattern formation can be regarded as function differentiation of a multi-agent system. When multiple autonomous robots without a given local task cooperatively work for a global objective, the function differentiation is the first and indispensable step. For example, each member of cooperative insects or animals can autonomously recognize own local tasks through mutual communication with local members. There were a lot of papers that reported a spatial pattern formation of multiple robots, but the global information was supposed to be available in their approaches. It is however almost impractical assumption for a small robot to be equipped with an advanced sensing system for global localization due to robot's scale and sensor size. The local information-based algorithm for the pattern formation is desired even if each robot is not equipped with a global localization sensor.

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We therefore propose a gradual pattern formation algorithm, i.e., a group of robots improves complexity of their pattern from to a simple pattern to a goal pattern like a polygon. In the algorithm, the Turing diffusion-driven instability theory is used so that it could differentiate roles of each robot in a group based only on local information. In experiment, we demonstrate that robots can make a few polygon patterns from a circle pattern by periodically differentiating robot's roles into a vertex or a side. We show utilities of the proposed gradual pattern formation algorithm for multiple autonomous robots based on local information through some experiments.


*Keywords:* Pattern formation; Homogeneous system; Turing diffusion-driven instability; Function differentiation; Autonomous robot

## 1. Introduction

Recently, a pattern formation of an autonomous robot group has been studied toward a multifunctional robot system that can arrange their own organization according to a given task and change of a surrounding environment. The autonomous formation of a spatial pattern is one of key technologies for the advancement of cooperative robotic systems. When multiple autonomous robots given no decomposed task cooperatively work for a global objective, the function differentiation is the first and indispensable step for it. For example, each member of cooperative insects or animals can autonomously recognize own local tasks for a global task such as keeping their lives through mutual communication with local members. As the ultimate goal, the system designers have to pay less attention to robot's configurations while robots manage to keep working by changing their own configurations or roles according to a task and an environment. Therefore a reconfigurable robot system is one of desirable robot systems. As one of the problems of function differentiation, we focus the pattern formation of homogeneous robot group.

As a pioneering study about reconfigurable robot system, Fukuda proposed the concept of CEBOT (Cellular Robotic System), that is modeling a cooperative system of biology. A number of cells compose a tissue, tissues compose a organ, and organs compose a human. Finally humans organize a group or a society. In the same way, some functional mechanisms composes a robot according to a purpose, and multiple robots cooperatively work more complicate task. The CEBOT study reported that heterogeneous mechanical components experimentally organize by themselves according to a given global task [1].

On the contrary, a homogeneous robot group has more advantages on the point of robustness and productivity if the robot group could achieve a global desired task. A task allocation or arrangement mechanism through an internal negotiation is absolutely imperative in homogeneous robot system. The studies