Chapter 10
A Multi-Robot System Using Mobile Agents with Ant Colony Clustering

Yasushi Kambayashi  
Nippon Institute of Technology, Japan

Yasuhiro Tsujimura  
Nippon Institute of Technology, Japan

Hidemi Yamachi  
Nippon Institute of Technology, Japan

Munehiro Takimoto  
Tokyo University of Science, Japan

ABSTRACT

This chapter presents a framework using novel methods for controlling mobile multiple robots directed by mobile agents on a communication networks. Instead of physical movement of multiple robots, mobile software agents migrate from one robot to another so that the robots more efficiently complete their task. In some applications, it is desirable that multiple robots draw themselves together automatically. In order to avoid excessive energy consumption, we employ mobile software agents to locate robots scattered in a field, and cause them to autonomously determine their moving behaviors by using a clustering algorithm based on the Ant Colony Optimization (ACO) method. ACO is the swarm-intelligence-based method that exploits artificial stigmergy for the solution of combinatorial optimization problems. Preliminary experiments have provided a favorable result. Even though there is much room to improve the collaboration of multiple agents and ACO, the current results suggest a promising direction for the design of control mechanisms for multi-robot systems. In this chapter, we focus on the implementation of the controlling mechanism of the multi-robot system using mobile agents.

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INTRODUCTION

When we pass through the terminals of an airport, we often see carts scattered in the walkways and laborers manually collecting them one by one. It is a dull and laborious task. It would be much easier if carts were roughly gathered in any way before collection. Multi-robot systems have made rapid progress in various fields, and the core technologies of multi-robot systems are now easily available (Kambayashi & Takimoto, 2005). Employing one of those technologies, it is possible to give each cart minimum intelligence, making each cart an autonomous robot. We realize that for such a system cost is a significant issue and we address one of those costs, the power source. A powerful battery is big, heavy and expensive; therefore for such intelligent cart systems small batteries are desirable since energy saving is an important issue in such a system (Takimoto, Mizuno, Kurio & Kambayashi, 2007; Nagata, Takimoto & Kambayashi, 2009).

To demonstrate our method, we consider the problem of airport luggage carts that are picked up by travelers at designated points and left in arbitrary places (Kambayashi, Sato, Harada, & Takimoto, 2009). It is desirable that intelligent carts (intelligent robots) draw themselves together automatically to make their collection more efficient. A simple implementation would be to give each cart a designated assembly point to which it automatically returns when free. It is easy to implement, but some carts would have to travel a long way back to their assigned assembly point, even if they found themselves located close to another assembly point. The additional distance traveled consumes unnecessary energy since the carts are functionally identical.

To ameliorate the situation, we employ mobile software agents to locate robots scattered in a field, e.g. an airport, and make them autonomously determine their moving behavior using a clustering algorithm based on ant colony optimization (ACO). ACO is a swarm intelligence-based method and a multi-agent system that exploits artificial stigmergy for the solution of combinatorial optimization problems. Preliminary experiments yield a favorable result. Ant colony clustering (ACC) is an ACO specialized for clustering objects. The idea is inspired by the collective behaviors of ants, and Deneubourg formulated an algorithm that simulates the ant corps gathering and brood sorting behaviors (Deneuburg, Goss, Franks, Sendova-Franks, Detrain & Chretien, 1991).

We have studied a few applications of the base idea for controlling mobile multiple robots connected by communication networks (Ugajin, Sato, Tsujimura, Yamamoto, Takimoto & Kambayashi, 2007; Sato, Ugajin, Tsujimura, Yamamoto & Kambayashi, 2007; Kambayashi, Tsujimura, Yamachi, Takimoto & Yamamoto, 2009). The framework provides novel methods to control coordinated systems using mobile agents. Instead of physical movement of multiple robots, mobile software agents can migrate from one robot to another so that they can minimize energy consumption in aggregation. In this chapter, we describe the details of implementation of the multi-robot system using multiple mobile agents and static agents that implement ACO. The combination of the mobile agents augmented by ACO and mobile multiple robots opens a new horizon of efficient use of mobile robot resources. We report here our experimental observations of our simulation of our ACC implementation.

Quasi-optimal robot collection is achieved in three phases. The first phase collects the positions of robots. One mobile agent issued from the host computer visits scattered robots one by one and collects the position of each. The precise coordinates and orientation of each robot are determined by sensing RFID (Radio Frequency Identification) tags under the floor carpet. Upon the return of the position collecting agent, the second phase begins wherein another agent, the simulation agent, performs the ACC algorithm and produces the quasi-optimal gathering positions for the robots. The simulation agent is a static agent that resides in
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