Chapter 101
Mobile Target Tracking of Swarm Robotics in Unknown Obstructive Environment

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ABSTRACT

This paper considers the problem of tracking a mobile target in an obstructive environment using a swarm of simple robots with limited sensing and communicating abilities. The target-tracking procedure, which has not been paid attention in previous swarm robotic researches, is specially focused. In tracking phase of problem, the swarm should move with low energy cost while keeping the target in sight. This mobile target tracking (MTT) problem, is useful for practical applications, such as escorting, monitoring, group carrying and etc. A spring virtual force (SVF) model is proposed to solve MTT problem and is applied on a self-built simulation program written by the authors in both ideal and noisy environments. The simulation results demonstrate that the proposed model has great advantages in finding target, saving energy and maintaining connectivity with fewer parameters, smaller computation overload and higher stability. The SVF model can achieve great performance even when there exists significant amount of noise.

INTRODUCTION

Biologists have observed self-organizing and adaptive behaviors in social animals like birds, fish, ants or bees (Giardina, 2008). It is surprising that each individual member follows a small number of simple behavioral rules, resulting in sophisticated group behaviors (Meehan, 1975). Diwold et al (2011) showed how a swarm can still fly towards a common direction even when the location of the nesting site is not known with precision. Modeling the simple behaviors that enable a group of animals to move in very elegant coordinated fashion, can in fact allow the design of groups of artificial agents which are able to move along the same direction, without the need of central coordination (Stranieri, 2011).

DOI: 10.4018/978-1-5225-1759-7.ch101

Swarm robotics, inspired from natural swarms, introduces the cooperating mechanism from the nature to control simple individual robots which are restricted to have limited functions, such as local sensing and communication, low computational resources and no central commanders in the swarm. In a swarm robotic system, although each single robot is fully autonomous, the swarm as a whole can solve problems that a single robot cannot cope with because of physical constraints or limited behavioral capabilities (Baldassarre et al, 2007). Despite the large population, it is worthy due to fault tolerance, higher efficiency and ability to cover wider areas.

Swarm robotics takes the advantage of the emergent behaviors from large population of simple individuals. The robots and strategies should be designed as simple as possible while promising the co-operation strategy among robots which plays the key role in swarm robotics. In this way, the algorithms should avoid complicated operations, such as large amount of direct communication or sensing specific objects, if such results can be simulated or bypassed through careful design of the algorithm. This makes algorithms of swarm robotics simple, elegant and scalable (McLurkin & Smith, 2007).

Target tracking problem has been introduced by researchers in other areas, such as game theory (Chung et al, 2011). They normally focus on planning robots' paths and predicting movements of targets. In these problems, the environment situation is known and the target is always traceable, thus few individuals can solve the problems well. However, when the target becomes untraceable and the environment becomes large and unknown to the individuals, the problem turns to be searching and tracking in a large and unknown space which cannot be solved using traditional methods. Thus, swarm robotic system is required for solving such problems.

In this chapter, the main focus is the mobile target tracking (MTT) problem of a swarm of homogeneous robots with limited sensing, communication and computation abilities. The swarm searches in large space with obstacles with unknown distributions. In previous swarm robotics studies, little attention has been paid to tracking behavior compared with flocking. However, many practical applications require post-operations after finding the target such as escorting, tracing or guarding. Therefore, we believe the tracking behavior, which is simplification of escorting and tracing, is very important from practical point of view.

The MTT problem is divided into three phases: flocking, searching and tracking. In the flocking phase, the swarm moves through an environment containing obstacles towards the target area, centered at the latest target location the swarm has detected. The searching phase is triggered if the target has left when the swarm flocks to the area. Once an individual finds the target, it informs the swarm and the whole swarm goes into tracking phase and starts to follow the moving target, trying to keep it in the sense range of any robots. Whenever loses the target, the swarm returns to searching phase and searches for the target.

A spring virtual force (SVF) model is proposed to solve the MTT problem based on virtual force mechanism. Several evaluation criteria are also proposed for the MTT problem based upon these phases to evaluate the proposed SVF model in this chapter. Some of the criteria focus on flocking and others specially concern searching and tracking. Since the main focus stays in tracking phase in this chapter, criteria for evaluating tracking phase is specially emphasized. These criteria can help analyze the performance of proposed algorithm and comparing algorithms in areas that concern most.

The rest of the chapter is organized as follows. First, we present related works inspired from biological studies of swarm robotic flocking, formation and obstacle avoiding in Section 2. Details of the proposed