Chapter 1
A Survey on Swarm Robotics

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ABSTRACT

In this chapter, the current work on swarm robotics is briefly reviewed. Swarm robotics, inspired from nature swarm, is a combination of swarm intelligence and robotic, and shows great potential in several aspects. Firstly of all, the cooperation in nature swarm and swarm intelligence is briefly introduced, and the special features of the swarm robotics compared with single robot and other multi-individual systems is also presented. Then we describe the modeling method for swarm robotics and list several widely used swarm robotics entity projects and simulation platforms for interested researchers. Finally, as the main point of this chapter, we summarize the current researches on swarm robotic algorithms, i.e., cooperative control mechanisms for swarm robotics for flocking, navigating and searching applications.

INTRODUCTION

Cooperation in Nature Swarms

Most swarm intelligence researches are inspired from how nature swarms, such as social insects, fishes or mammals, interact with each other in the swarm in real life (Bonabeau, Dorigo, & Theraulaz, 1999). These swarms range in size from a few individuals living in small natural areas to highly organized colonies that may occupy large territories and consist of more than millions of individuals. The group behaviors emerged in the swarms show great flexibility and robustness (Camazine, 2003), such as path planning (Vittori et al., 2006), nest constructing (Theraulaz, Gautrais, Camazine, & Deneubourg, 2003), task allocation (Beshers, & Fewell, 2001) and many other complex collective behaviors in various nature swarm as shown in (Barbaro et al., 2009; Menzel, & Giurfa, 2001; Thorup, Alerstam, Hake, & Kjellén, 2003).

Individuals in the nature swarm shows very poor abilities, yet complex group behaviors can emerge in the whole swarm, such as migrating of bird crowds and fish schools and foraging in ant and bee colonies. It's tough for an individual to complete the task itself, even a human being without certain experiences can find it difficult, but a swarm of animals can handle it easily. Researchers have observed intelligent group behaviors emerging from a group of individuals with poor abilities through local communication and information transmission.

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- **Bacteria Colonies:** Bacteria often function as multicellular aggregates known as biofilms, exchanging molecular signals for inter-cell communication (Shapiro, 1998). Communal benefits of multicellular cooperation include a cellular division of labor, collectively defending against antagonists, accessing more resources and optimizing population survival by differentiating into distinct cell types. Bacteria in biofilms have shown more than 500 times increased resistance to antibacterial agents than individual bacteria of same kind (Costerton, Lewandowski, Caldwell, Korber, & Lappin-Scott, 1995).
- **Fish Schools:** Fish schools swim in disciplined phalanxes and are able to stream up and down at impressive speeds and making startling changes in the shape of the school without collisions as if their motions were choreographed. Fishes pay close attention to their neighbors when schooling with the help of eyes on the sides of heads and "schooling marks" on their shoulders (Bone, & Moore, 2008). Fishes can benefit from fish schools in foraging (Pitcher, Magurran, & Winfield, 1982) and predator avoidance (Moyle, & Cech, 1988).
- **Ant and Bee Colonies:** Ants communicate with each other using pheromones, sounds, and touch (Jackson, & Ratnieks, 2006). An ant with a successful attempt leaves trail marking the shortest route on its return. Successful trails are followed by more ants, reinforcing better routes and gradually identifying the best path (Goss, Aron, Deneubourg, & Pasteels, 1989). Experiments in (Ravary, Lecoutey, Kaminski, Châline, & Jaisson, 2007) suggest that arts can choose roles based on previous performance. Ants with higher successful rate intensified their foraging attempts while the others ventured out fewer times or even change to other roles.
- **Locusts:** Buhl et al. (Buhl et al., 2007) confirmed the prediction from theoretical physics that as the density of animals in the group increases, the group rapidly transit from disordered movement of individuals to highly aligned collective motion. They also demonstrated a dynamic instability in motion that groups can switch direction without external perturbation, potentially facilitating the rapid transfer of directional information.
- **Bird Crowds:** From long time ago, human makes use of birds' ability to precisely location home more than 5,000 kilometers away. Birds gather into special formations during migration and locate the destinations with the aid of a variety of senses including sun compass, time calculation, magnetic fields, visual landmarks as well as olfactory cues (Wallraff, 2005).
- **Primates:** Cooperation among primates can be complex, such as make tools and use them to acquire food and for social displays, deception (Parr, Winslow, Hopkins, & de Waal, 2000), recognize kin and conspecifics (Parr, & de Waal, 1999) and learn to use symbols and understand aspects of human language. Primates also use vocalizations, gestures, and facial expressions to convey psychological state.
- **Human Beings:** Dyer et al. (Dyer et al., 2008) has shown leadership and consensus decision making can occur without verbal communication or obvious signaling in a group of humans. They found that a small informed minority could guide a group of naïve individuals to a target with improved time and accuracy efficiency to the target. Even when conflicting directional information was given to different members, consensus decision can be made highly efficiently.

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