Chapter 92
Security in Swarm Robotics

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ABSTRACT

Inspired by social animals, such as ants, bees and fish, which appear to exhibit what has been dubbed 'swarm intelligence', swarm robotic systems aim to accomplish goals that are unachievable by an individual robot. Swarm robotics have a large number of potential uses, including applications in the military, monitoring, disaster relief, healthcare and commercial applications. To be able to achieve their goals, it is of utmost importance that communications between agents are secure in the presence of possibly malicious interruptions and attacks from adversaries. The authors will discuss the issues surrounding the provision of secure communications in swarm robotics: what secure communications mean, how the characteristics of swarm robotics present a security challenge, the relationship between security issues for swarm robotics and other network technologies, and how different adversarial models demand different types of solutions. It will then be discussed what the important open research questions are in secure communications in swarm robotics.

INTRODUCTION

Swarm robotics is concerned with the coordination of large numbers of relatively simple robots. Although there is no universally accepted definition for swarm robotic systems, Şahin (2005) proposes the following working definition: *swarm robotics is the study of how a large number of relatively simple physically embodied agents can be designed such that a desired collective behaviour emerges from the local interactions among agents and between the agents and their environment*.

Swarm robotic systems aim to accomplish goals that are unachievable by an individual robot. In a number of situations, having numerous simple robots forming a swarm, rather than an individual complex robot, could be beneficial as it may be cost effective or achieve the set goal more effectively. Because of this, swarm robotics have a large number of potential uses, including applications in the military, medical scenarios, disaster relief, monitoring and commercial applications (Şahin, 2005).

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Şahin (2005) explicitly puts forwards five characteristics as criteria for distinguishing swarm robotics from other multi-robot research in Section 3 of his paper. Şahin suggests these characteristics as a way to differentiate swarm robotics from other multi-robot systems. His five defining characteristics of swarm robotics are:

1. **Autonomous Robots:** Robots are able to act without the direct intervention of humans and have control over their own actions and internal state.
2. **Large Number of Robots:** Closely linked to the idea of scalability, there should be a large number of robots, or studies should be applicable to the control of large robotic swarms.
3. **Consist of a Few Homogeneous Groups of Robots:** The swarm network should consist of relatively few groups of homogeneous robots.
4. **Relatively Incapable or Inefficient Robots:** On an individual level, the robots should be relatively simple and either incapable of completing tasks individually, requiring cooperation amongst the swarm to achieve the global goal, or working as a group should improve the performance and robustness of the handling of the task.
5. **Local Sensing and Communication Capabilities:** The robots should have local and limited sensing and communication abilities to ensure distributed coordination amongst the swarm. A global communication channel may be used to download a common program onto the swarm, however this should not be used for coordination amongst the robots (as this is likely to be unscalable) and the communication is considered to be one way, in the direction from the channel to the swarm.

Other characteristics not explicitly listed by Şahin (although some are implicit) include:

6. **Co-Operate to Accomplish Tasks:** As the robots are relatively incapable or inefficient, they are required to, or would benefit from, cooperating to complete any given tasks.
7. **Mobile:** The robots are mobile. It is generally assumed their movement is not predictable. Sometimes, however, the robots may be bounded to movement within a predetermined boundary.
8. **Self-Organising:** Swarms should be self-organising, defined by Camazine, Deneubourg, Franks, Sneyd and Theraulaz (2002), as *the process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system*.
9. **Collective Emergent Behaviour:** A collective behaviour emerges from the local interactions among agents and between the agents and their environment.
10. **Decentralised Control:** The individual robots must operate on local information obtained to accomplish global goals. There is no central point of control in the system and coordination is completely distributed. This characteristic contributes to achieving robustness, as there is no common node failure point or vulnerability (Winfield & Nembrini, 2006).
11. **No Individual Identity:** In a swarm, there are relatively few groups of homogeneous robots. In each homogeneous group, the robots can be identical, as they do not need to be individually identified. Thus individual identification is not necessarily required.
12. **Lack of Synchronicity:** As described by Beni (2005), the units of the swarm do not move synchronously or sequentially, but interact dynamically.
13. **Range of Communication:** Swarms use both explicit and implicit communication methods. Explicit communications are where one robot communicates directly with another. Such methods of communication include radio frequency and infra-red technologies, which have previously been well

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