

Chapter 61

An Overview of Swarm Robotics for Search and Rescue Applications

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ABSTRACT

The area of research presented in this chapter focuses on swarm robotics, which is a particular domain of multi-robot systems (MRS) that embodies the mechanisms of swarm intelligence into robotics. More specifically, this chapter overviews the applicability of swarm robotic solutions into search and rescue (SaR) real-world missions. In this chapter, SaR operations are considered as a vital target application wherein swarm robotics can be applied due to their inherent level of complexity. Such operations often occur in highly dynamic and large scenarios, with harsh and faulty conditions, that pose several problems to traditional MRS applicability. This chapter focuses on these problems highlighting the challenges that cannot be handled appropriately by simple adaptation of traditional algorithms, planning, control and decision-making techniques.

INTRODUCTION

The creation of artificial devices with life-like characteristics has been pursued over the last two millennia, beginning, as so many things in our modern world did, in Ancient Greece. More recently, mainly in the last two decades, a significant progress in applied computing and robotics occurred through the application of principles derived from the study of biology. The navigation of groups of robots, especially swarm robots, has been one of the fields that has benefited from biological inspiration (Bonabeau, Dorigo, & Theraulaz, 1999).

Nevertheless, until recently, swarm robotics applicability has been kept far from real-world missions, such as search and rescue (SaR). To cross the reality gap inherent to MRS and, in particular, swarm robotics, many initiatives^{1,2} and worldwide research and development (R&D) efforts have been focusing on the full-scale deployment of such systems in real-world application environments. This chapter

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essentially revolves around *SaR* applications as they cover most of the challenges encountered in real-world applications. Those applications are regularly classified by some specific features that pose several problems, especially in terms of inter-robot communication, in which we can highlight the following ones (Murphy, et al., 2008):

- **Large:** Dimensions of real applications do not stick to laboratorial *testbeds*, going from hundreds of square meters (*e.g.*, manmade disasters) to hectares of land (*e.g.*, natural disasters);
- **Highly Dynamic:** Scenarios change over time, either due to agents' mobility and actions or due to external factors (*e.g.*, collapses, fires, floods, earthquakes, explosions);
- **Harsh and Faulty:** Abundant presence of abrasive dust, water, chemical substances and a wide range of obstacles in the scenarios;

It is with these real-world problems in mind that swarm robotics is seen as the most promising class of multi-robot systems (*MRS*). Those techniques offer several major benefits over the conventional search techniques, such as the robustness of the swarm to individual units failure or run-time addition of new units, the scalability of emergent behaviours to swarms of different sizes, the leveraging of self-organization principles of environmental noise and individual differences, and the synergetic effect whereby the work of the swarm is greater than the sum of the work by the individual units (known as superlinearity) (Floreato & Mattiussi, 2008) – a concept shared by other fields, such as complex systems.

On these grounds, other examples of potential applications for swarm robotics include military missions, unmanned space exploration, environmental data collection, and others. However, regardless the application type, all of them require two particular features: a distributed architecture and inter-robot communication.

The first feature is common within swarm robotics context, in which tasks are inherently distributed in space, time, or functionality. Nevertheless, it should be noted that some works still emphasize on centralized architectures (Li, Alvarez, De Pellegrini, Prabhakaran, & Chlamtac, 2007), thus moving away from the fully distributed nature inherent to the principles of collective intelligence. In practice, centralized swarm architectures are computationally expensive and unsuitable as a large number of robots usually generates very dynamic behaviours that a centralized controller cannot handle (Sahin E., 2005). Also, centralized architectures lack robustness as the failure of the centralized entity may compromise the performance of the whole *MRS* (Parker L. E., 2008a).

Regarding the second feature, the inter-robot communication, many different swarm robotic algorithms have been proposed recently in the literature with different communication paradigms, going from completely implicit communication to explicit communication. In algorithms under explicit communication, robots need to be able to explicitly exchange information within a network path using some sort of a medium (*e.g.*, wireless communication). Despite such requirement, the choice of explicit communication over alternatives, such as *stigmergy*³, relies on the application domain of realistic applications, such as *SaR*. According to the current state-of-the-art in this field, robotic technology is used, almost exclusively, to assist and not to substitute human responders (Murphy, Human-robot interaction in rescue robotics, 2004). Hence, multiple mobile robots can take advantage of parallelism to reduce the time required to fulfil the mission, while explicitly providing important data about the site (*e.g.*, contextual information), whether accessible or inaccessible for human agents. To do so, they need to be endowed with an explicit communication medium.

With these features and assumptions in mind, next section presents the typical *SaR* procedure.

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