

# Chapter 1

## Introduction

New progresses in robotics have opened a new branch of studies. Taking inspiration from social animals like ants, bees or fishes, researchers are now able to create groups of robots performing tasks that could not be undertaken individually. These groups are called swarms. We envision swarm robotics to be useful for applications like search and rescue, environment exploration, or oil spill cleaning (Dorigo et al., 2014). In swarm robotics system, each robot executes the same controller code. The interaction between the robots and between the robots and the environment enable the emergence of a collective behaviour. There is no hierarchy in the swarm. That is, all the robots behave autonomously. Research in swarm robotics is important as it underpins potential future disruptive innovations. Nanorobotics is going to be one of these innovations. The use of nanorobotics in medicine will grow over the next years. It could be one of the future solutions to cure cancer or other diseases by targeting the faulty constituents of the body with a swarm of very small robots. Swarm robotics is also important because it could constitute an adequate solution to other real problems. Swarm robotics systems are robust, i.e., losing a robot of the swarm is not a critical issue. Some tasks are dangerous for humans (e.g., demining, search and rescue) and the use of robots is preferred to avoid any injuries. However there is also a high risk of losing robots. Hence this task requires a fault-tolerant approach that swarm robotics can provide. Thanks to their scalability and flexibility, swarm robotics solutions are also suitable for applications where it is difficult to estimate the resources needed to carry out the task (e.g., search and rescue, cleaning). Swarm robotics solutions quickly adapt to new operation conditions and are thus appropriate for tasks in environments that change over time (e.g., patrolling, disaster recovery, and search and rescue). Since the robots behave autonomously, swarm robotics solutions are also suitable for large or unstructured environments where no infrastructure, like a communication system

or a global localisation system, can be used to control the robots. Examples are underwater or extra-terrestrial planetary exploration, surveillance, demining, and search and rescue (Dorigo et al., 2014).

Even though swarm robotics can carry out tasks autonomously, they do not have a global understanding of the environment and of the task that they must carry out. A human operator can, therefore, interact with those swarm systems to issue them commands (i.e., what type of tasks to carry out and where to carry out the task). Issuing commands relies on a one-way communication between the human and the swarm of robots. For swarm robotics to be adopted outside of research laboratories and tackle real world issues, one should always be able to take control of the swarm at any time. This is a legitimate safety requirement when considering the use of a large amount of potentially harmful robots around humans. Hence one can understand the vital aspect of the interaction between human and swarms of robots. In this thesis, however, we did not implement a method granting the human to completely control the swarm. We leave it as a future work. For the purpose of this thesis, it was not necessary.

To date, little attention has been paid to robotics swarm feedback, i.e., messages sent from the swarm to the human operator. Most of the research works focus on issuing commands to swarms. However, there might be situations in which the human does not know everything (e.g., where a gas leak comes from). For instance, we can leverage swarm robotics systems to help humans move in dangerous environments. To the best of our knowledge, no study has considered a human being escorted by a swarm of robots in a dangerous environment.

In this thesis we make an attempt to address this lack of consideration. We study how a swarm of robots can help a human move in dangerous environments. We use inspiration from flocking and pattern formation to allow a swarm of robots to prevent a human from entering dangerous areas. In this thesis, these dangerous areas are invisible to the human. These dangerous areas could, for instance, contain mines or be radioactive, or present another type of danger (e.g., poisonous gas, unstable floor). In order for the human to avoid these dangerous areas, we designed a swarm system that escorts the human in an environment. There is a bidirectional feedback between the swarm and the human. The robots warn the human about the danger, and the human indirectly controls the position of the robots by changing his/her position. It contrasts with most of the studies that only contain a unidirectional feedback (the human controlling the swarm). For the robots to stay around the human, we had to find a way to make the human detectable for the robots. We built an entirely new portable

device for that purpose.

Our solution went through a series of tests. The majority of the tests was used to incrementally improve the solution. These tests were made in a simulator and on real robots. At the end of the implementation, more tests were performed to assess the quality of the solution. Overall results are promising: the robots are following the human and warn him/her about near dangers.

This thesis is outlined as follows. In chapter 2 we present studies related to this master thesis. We introduce swarm robotics and provide a state of the art in human - robots interaction, and human - robotic swarm. In chapter 3 we expose the problem we address in more details. We also provide a complete description of our solution. Chapter 4 contains detailed explanations on the tests we conducted. Finally we conclude our work in chapter 5.