Chapter 5

Conclusion

In this thesis, the problem we addressed was to provide a protection to a human walking in a dangerous environment. This dangerous environment contains dangerous areas that must be avoided. These areas could be mines or radioactive areas. The human is unable to perceive them. We addressed this problem with an approach based on swarm engineering. We decided on the E-pucks (Mondada et al., 2009) as robotic platform to form a swarm encircling a human. The swarm is augmenting the capabilities of the human. The human is able to perceive danger that he would not be able to perceive without the help of our robotic system. The controller is based on the principles of virtual physics and pattern formation. One of the challenges we had to address was to make the robots detect the human. In order to allow robots to detect the human, we build a portable device. We built shoes with coloured LEDs that the robots can detect with their camera.

We conducted multiple experiments in simulations and with real robots to show that our solution addresses our problem. We characterised the system composed by the swarm of robots and the shoes. We tested the range of detection of the shoes to see how far away the robots could detect them. The maximum distance we obtained is sufficient for our purpose, but not for real applications. We also analysed the time needed by the robots to form a circle around the human from different starting positions. We obtained the best results for the starting configuration where all the robots are randomly placed in the arena. On the other hand we obtained longer delays for the configuration where all the robots are clustered near the shoes. However, in all the cases, the robots surrounded the human. We ran an experiment with a human walking with the augmented shoes towards a dangerous area. The human was correctly warned by the robots in contact with the dangerous area.

Even though our solution satisfied our main problem (i.e., how to protect a human from going into dangerous areas), we believe that the current implementation of our solution has some limitation. First of all, the speed of the robots is too low for a real application. We made a comparison of the two speeds in section 4.1.1. The average speed of a human is 5 km/h (1.39 m/s). The maximum speed of the robots is 0.1 m/s. Faster robots would be needed for real applications. The scope of the omnidirectional camera is acceptable in our case, but in a real application it would be better if the robots detect the human from farther. The omnidirectional camera that the robots use to detect the human colour blobs is too sensitive to light conditions. Another sensor that is more robust with respect to the conditions of the experiments would be better. It could be interesting, as future work, to implement our solution on an other robotic platform, e.g., the foot-bot, mounted with a more precise camera (Dorigo et al., 2013). The robotic platform we used is only suitable for flat surfaces. However the outside real environments are everything but flat. Furthermore, for the purpose of a real life experiment, the robots would need batteries with higher capacity.

Future Works This solution can be enhanced by other future works. Here are the main following works that we think could be interesting.

Other Robots The next steps for this solutions could be to export the controller to other robots. These robots would be more able to operate in a real environment. As mentioned above, one could also upgrade the solution with better sensors for detecting the human and other robots. The first step could be to implement our solution on the foot-bot platform which has tracks and wheels, and a better camera (Dorigo et al., 2013).

Guidance Once enhancements on the hardware side have been realised, one could update the controller to perform other related activities. One interesting application one could look into is guidance. The human would have less freedom of movement. Instead, the robots would encircle the human and help him to move in a previously computed and optimised direction. Guidance could also apply to animals. Below are presented 3 examples of guidance:

◎ **Vehicle Guidance:** This application is very similar to our project: helping someone or a vehicle that cannot see the danger augment his/her/its abilities to detect it. One could imagine a vehicle whose driver cannot see the danger because of unusual circumstances (smoke, fog). For example, one could imagine a boat entering an unsafe region of the sea (shallow water, streams) or a harbour. In the case of the harbour, the robots would also act as buoys or shock absorbers. In the future, a greater part of vehicle will operate without a driver. Guidance could also be extended to driverless vehicles. These vehicles would be encircled by a swarm of robots to progress safely towards the destination. If we consider a boat without a driver, the robots acting as shock absorbers around the boat in the harbour are interesting.

◎ **Human Motion Synchronisation:** The second application we thought about was the synchronisation of multiple humans. One can imagine a restricted area where rounds have to be made. With the help of the robots, the 'swarm of humans' could cover a wider area by synchronising their progression and walking speeds. In case of intrusion or attack, the robots could help to defend the human with additional equipment (shields, aimbots, additional ammunition).

◎ **Crowd Control and Fishing:** A swarm of robots could also act as a crowd container to limit important crowd movements or to channel the flow of humans by forming barriers along the path. The same idea could be used for fishing. One could build robots that imitate fish behaviours to avoid frightening them and encircle schools of fishes. The robots would then release nets around the swarm of fishes that would connect to each other to form a sphere.