Human - Robots Swarms Interaction

An Escorting Robot Swarm that Diverts a Human Away from Dangers One Cannot Perceive

Anthony Debruyn

August 17, 2015

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 [1]. 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 [1].

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 (see Figure 1) 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. The robots encircle the human. 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. The swarm is augmenting the capabilities of the human. The human is able to perceive dangers that he would not be able to perceive without the help of our robotic system. It contrasts with most of the studies that only contain a unidirectional feedback (the

Fig. 1. The robotic platform we used: the E-puck.

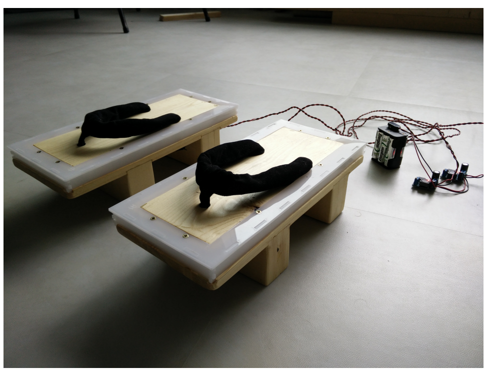
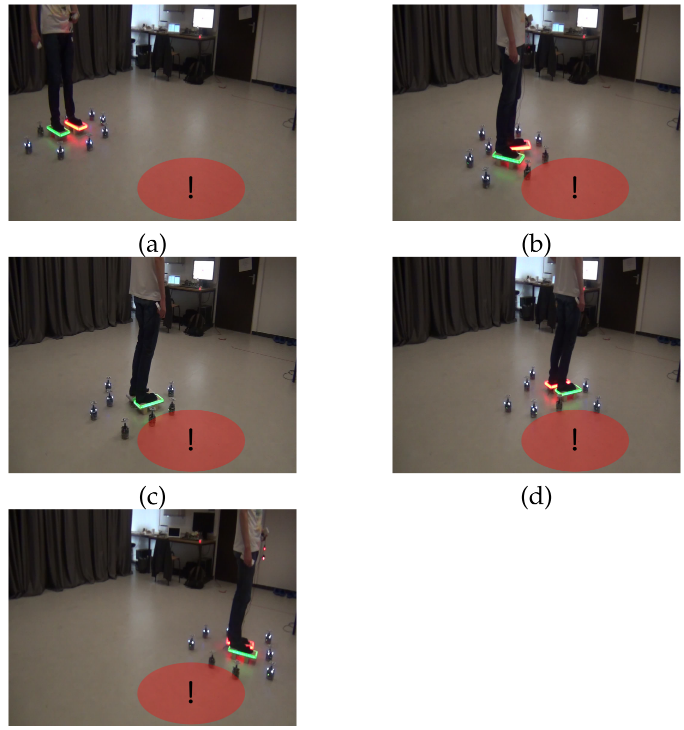


Fig. 2. The augmented shoes.

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: augmented shoes with coloured LEDs that the robots can detect with their camera (see Figure 2).

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 by performing more tests: 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 (this configuration is similar to a storage configuration). However, in all the cases, the robots surrounded the human. We ran an experiment with a human walking with the augmented shoes towards a virtual dangerous area (see Figure 3). The robots in contact with the dangerous area correctly warned the human. 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 limitations. These limitations could be investigated as future works.



(a) (b) (c) (d) (e)

Fig. 3. Screenshots from the video of an experiment. The virtual dangerous area is added as an overlay as a red disc.

Acknowledgments

The author would like to thank Mauro Birattari, Gaëtan Podevijn, Andreagiovanni Reina, Anthony Antoun, Brian Delhaisse, Lorenzo Garattoni and the IRIDIA laboratory for their precious help and the hardware provided.

References

[1] M. Dorigo, M. Birattari, and M. Brambilla, “Swarm robotics,” vol. 9, no. 1, p. 1463, 2014, revision 138643.

Contacts

Anthony Debruyn – Author
Email: adebruyn@ulb.ac.be
Mauro Birattari – Promoter
Email: mbiro@ulb.ac.be

Marco Dorigo – Co-promoter
Email: mdorigo@ulb.ac.be
Gaëtan Podevijn – Supervisor
Email: gpodevij@ulb.ac.be
Andreagiovanni Reina – Supervisor
Email: areina@ulb.ac.be