Evolutionary Swarms of Flying Robots

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In case of a wide-area catastrophic event, rescuers often need a dedicated communication system allowing them to exchange information with a base station and with other rescuers. In this project, we are developing a swarm of small and light-weight flying robots that will autonomously locate the rescuers and establish a communication network with the base station (figure 1). The swarm of robots should be able to operate in various lighting conditions, including at night, and maintain the communication link if rescuers move around the area or if some robot fails.

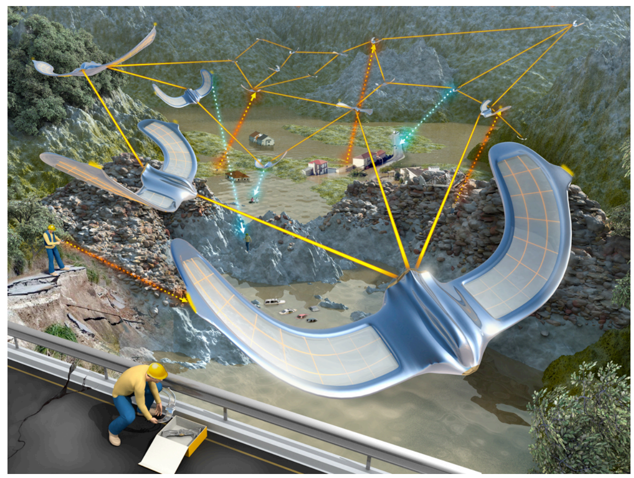

Figure 1. Artist's view of a deployable swarm of autonomous robots for ad hoc communication networks in case of catastrophic events.

The robot consists of a flying wing equipped with a pressure altimeter, a speed sensor, a magnetic compass, an Inertial Measurement Unit, a wireless radio-link, and a LinuX onboard computer for handling control and communication (the detailed description and demonstration of the robot can be found in another poster presentation [1]). For this project, the robot does not use vision and GPS. However, we are designing the robotic platform in such a way that it can be easily customized with several sensors and easily programmed by other researchers in the biological and engineering communities.

In a preliminary scenario, a swarm of 20 robots are manually launched from a box, search for one rescuer within a distance of 550 m, and reconfigure so to establish a reliable communication link between the rescuer and the launching location where the base station is supposed to be. Robots cannot rely on GPS and vision to know their own position and that of other robots. All a robot knows, is whether there is another robot within a surrounding area with a radius of 100 m, and how many robots away (hop count) it is from the base station and from the rescuer (if one has been found).

Hand-coding a suitable set of control systems for the swarm is difficult because, since the behaviors of the robots are locally and mutually dependent and cannot use an absolute referential system, small behavioral variations can have large and hard-to-predict consequences in the swarm dynamics. Therefore, we resorted to a process of artificial evolution to generate control systems that collectively achieve the goal scenario. Once a satisfactory control system was found, we reverse engineered the evolved controller into a control program that could be easily understood and modified according to the scenario constraints. (The use of a different, non-evolutionary, strategy based on ants is described in another poster presentation [2]).

Artificial evolution of collective control systems however is not yet well understood and, in particular, it is not clear how swarm fitness should be distributed among swarm members and how similar or different should the control system of swarm members be. We thoroughly investigated these two questions with the help of a swarm of wheeled robots and obtained guidelines for evolving swarms of individuals that must cooperate to achieve a collective task [3].

These guidelines were then applied to the swarm of flying robots in this scenario. We carried out all evolutionary experiments in simulation. The control systems of the robots consisted of a feed-forward neural network that was equal for all robots. The fitness function was the percentage of time a reliable communication was maintained by the swarm. Strategies found through evolution (figure 2), allowed for the establishment and maintenance of a communication link between the base station and rescuer.

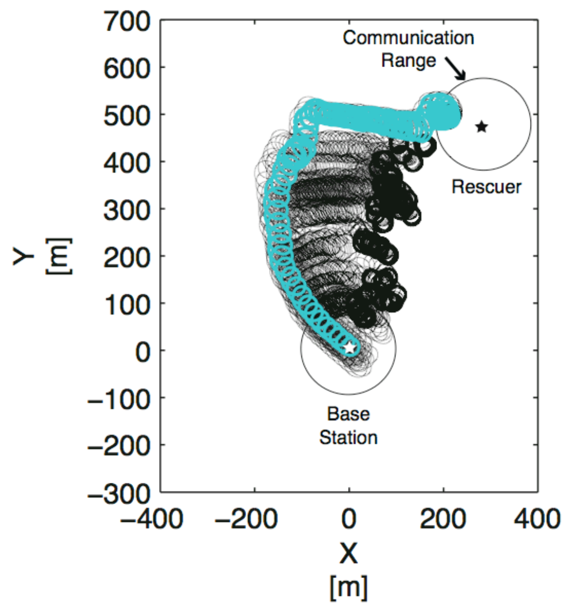

Figure 2. Flight trajectories of an evolved swarm that found a rescuer and established a communication link with the base station.

The trajectories of evolved control systems were analyzed and translated into two simple control principles. These rules were then implemented in the simulated swarm and its performance measured under various conditions. Given these promising results, some functionalities of the hardware, such as the turning radius of the robot, have been matched to the evolved control rules in order to ensure their porting from simulation to the physical robots.

References

[1] Leven, S. Zuffery, J-C. and Floreano, D. (2007) A Simple and Robust Fixed-Wing Platform for Outdoor Flying Robot Experiments. In this volume.

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[3] Floreano, D., Mitri, S., Magnenat, S. and Keller, L. (2007) Evolutionary Conditions for the Emergence of Communication in Robots. *Current Biology*, **17**, 514-519.