Chapter 3
Cockroach Inspired Shelter Seeking for Holonomic Swarms of Flying Robots

Hamoon Shahbazi
Luleå University of Technology, Sweden

Jan Carlo Barca
Monash University, Australia

ABSTRACT

In computer science, the study of mimicking nature has given rise to Swarm Intelligence, a distributed system of autonomous agents interacting with each other to collectively perform intelligent tasks. This chapter investigates how groups of holonomic flying robots such as quad copters can seek shelter autonomously when encountering bad weather. In this context three alternative autonomous shelter seeking techniques that address the unsolved plateau-problem had to be implemented. The methods were inspired by cockroaches and hunting strategies observed in apex predators. Previous studies on cockroaches have provided facts about their behaviour and resulted in algorithms that can be used for robotic systems. This research builds on these previous studies by formulating three alternative techniques and carrying out a comprehensive analysis of their performance. Simulation results confirm a scalable system where swarms of flying robots successfully find shelters in 3-D environments.

INTRODUCTION

Robotic systems have received significant attention over the last decades. We are on the verge of entering a new phase where the next generation of robotic technology is integrated in our daily lives. This may be beneficial in many ways. For instance, when humans are not prone to take on a certain task, robots can be used to avoid exposure to danger. In some cases robots replace humans for repetitive tasks or simply because they are more efficient in strength, speed or accuracy (Campo, 2010). Different types of robots (e.g. crawling, climbing or flying robots) engender their own unique benefits. For example, one of the many distinctive advantages of flying robots is their broad view coverage. In fact, these types of robots

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are used today to help Japanese farmers monitor their crops and spray pesticides (Greiner, 2013). Other UAS protect the wildlife in Africa by tracking poachers. The future of flying robots looks promising. For instance, swarms of tiny flying robots could quickly, safely and cost efficiently sweep and visually inspect infrastructures such as bridges and dams. The possible applications are almost endless, e.g. firefighting, police and border observation, search and rescue, mapping, radiation detection, damage observation and assessment (UAV Design, 2013). Some of these applications are already in the development stage (Liu et al., 2010). David G. Green (2014) mentions a prosperous future for swarm robotics with the evolution of nanotechnology. He mentions that small nano-bots can extract contaminants from different mixtures in food or even in our bodies (tracking and removing viruses). As the technology in this particular field will continue to evolve, surely the area of application can be extended even further. Perhaps even to planetary exploration, where flying robots can replace ground moving rovers or even satellites in search for life or close mapping on other earth-like planets (Påhlsson et al., 2011).

Before we can send robot swarms to other planets, we need to make sure they can survive on their own, i.e. make them completely autonomous. Robots used for outdoor missions are exposed to a world of harsh environments. Shelter seeking is for that reason very important if the robots shall remain independent. It is a self-defensive mechanism that may protect them in situations where there is a risk for mission, or even system failure. Shelters are not always easy to reach, and in some cases the capacity of a shelter is low, forcing the swarm formation to morph, by reducing the distance between each robot. For UAVs the minimum distance to objects is crucial to avoid inter-robot collisions and collisions with environmental objects. On top of that, flight instability may occur as a consequence of turbulent air, from e.g. the down-wash of a neighbouring rotor craft.

In cases where the shelter size is not sufficient to hold the entire swarm it may have to be split into multiple groups. A maximum distance has to be defined in order to prevent the robots from losing contact. Here the term connectivity becomes a key component in a dynamic swarm. A connected swarm ensures the continuous flow of information throughout the whole swarm. It may be interpreted as a condition on how scattered a swarm can become without breaking up into sub-swarms. This is important for each individual within the group to keep improving its own current position by using its neighbours as references.

We can now see that shelter seeking is a complex behaviour to implement in a swarm of robots. The lack of research in the field extends the difficulty even further. The problem is solvable though. In fact it has already been solved, by nature itself. For example, a cockroach has the ability to effectively seek shelter with the help of its friends and its love for darkness. Dark areas are usually signs of potentially good shelters against bad weather, e.g. rain and harsh winds, which roaches dislike and try to avoid (Ganihar et al., 1994). We can relate this to flying robots that may experience flight instability or electrical malfunctions due to turbulence, rain, lightning and other harsh weather conditions.

Because biological systems are so complex, biomimetics is applicable for a vast variety of fields. Over extremely long time and through natural selection, nature has evolved and adapted to solve engineering problems. Seeking inspiration from nature is a great place to start, because in most cases life has tackled similar problems which we are facing today. With traditional engineering methods it may become extremely difficult to design a new system because all possible scenarios have to be taken into consideration. In space engineering there is no room for mistakes. In 1961, during the Americas space race with the Soviet Union, an astronaut named Alan B. Shepard was sitting in the Mercury capsule in hope of becoming America's first man in space (Green, 2014). There had previously been little success and the space programme was therefore hanging by a thread. Because of the complexity of the thousand parts of the rocket system, the technicians had to check and recheck everything to make sure there was