POPULAR SCIENTIFIC ABSTRACT

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Finding bats, in the wild, with drone swarms

Multi-rotor drones, equipped with sensitive microphones, are being used to measure the ultrasound of bats hunting in the dark, but the bats must first be found. The Secret Life of Bats is a joint project between the Maersk Mckinney Moller Institute and the Bio-acoustics group of the Biology department, which aims to measure the behaviour of wild bats without influencing or affecting them in any way. Currently, measurement equipment is carried to areas where bats have been known to hunt, but this is not a full assessment of their hunting behaviour -- only a confirmation that they hunt this way at this location. Therefore, un-biased search algorithms must be used to measure bats wherever they may be. Go where the bats are, not where they sometimes go. It is, the aim of this thesis to explore different types of search algorithm to determine what characteristics affect their effectiveness at finding a target. Specifically, when that target is as fast, agile, and barely-visible as a bat hunting at night.

A simulation was developed in MATLAB to compare two main groups of algorithms: the fixed-path algorithms and the randomised-path algorithms. As the behaviour of the search target is critical to understanding the effectiveness of a search algorithm, a simulated bat was created as a realistic representation of a real bat. The searcher is also a vital part of a search algorithm and so the characteristics of the Secret Life of Bats drone and microphone array were also modeled in simulation. The simulation tested 2 fixed and 2 randomised search algorithms, each run 100 times per fixed drone speed (1 to 10ms^{-1}). When testing the time it took the algorithms to find the bat, it was found that the TSP algorithm significantly outperformed all other algorithms: consistently finding the bat within half the time of the other algorithms and almost never failing a test. A new fixed-path algorithm was created to mimic the characteristics of the randomised-path TSP and their results were significantly similar. It was proven that it is not the randomisation of a path that improves a spatial search algorithm, but fast expansion away from the origin with periodic trips towards the centre of the search area. The coverage of the search area achieved by the algorithms was also tested, alongside the effect of different battery lives, which ultimately determined that coverage contributes to the effectiveness of an algorithm but not as much as rapid expansion into the area.

Real-world testing took the form of an experiment where an artificial bat chirper, complete with ultrasonic transducer and simulated flight path, was created as the target. This experiment did not proceed past the safety testing stage due to significant delays caused by various accidents, public health concerns, and restricted access to hardware. Ultimately, the use of a drone for autonomously searching for bats in large areas at night has been deemed impractical and unsafe, until drones have become more robust, repeatable and more open to third party path planning.

Beyond the real-world tests, the expansion of the search problem to a multi-drone system was also explored. If one searcher is capable of finding a bat within a reasonable time, it is logical to expect that the time will improve with more drones and increase the time spent in the presence of a bat. When more drones are added to make a swarm, there are new considerations that must be addressed, such as whether or not all drones use the same algorithm or if each drone gets a slightly modified version, etc. Therefore, the simulation was modified to test the multi-drone searches. The TSP was most effective with one drone and was the most effective all the way up to five drones. The new algorithm, that matched the TSP with one drone, stopped improving at three drones. The use of multiple drones flying each of these algorithms in the real-world was also explored and it was determined that the fixed-path algorithms (the safest with one drone) were significantly more dangerous as more drones are added.