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SELF-ORGANISING SWARMS OF FIREFIGHTING DRONES

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Abstract. Wildfires are major hazardous events which have devastating socio-economic and environmental impacts, including the loss of human lives and biodiversity, health deterioration, destruction of infrastructures and economic activity, soil degradation, and climate change. They are estimated to contribute with 20% of the global greenhouse gas emissions per year. By 2030, wildfires could destroy 55% of the Amazon rainforest in addition to the 20% that has already been destroyed, resulting in the Earth largely losing its ability to absorb greenhouse gases. Therefore, the development of more effective and safer means to fight wildfires is one of the worlds most pressing challenges of our time. Given the increasing severity and frequency of wildfires, the use of robots in place of humans is of special interest. Drones have been widely used for wildfire monitoring and detection, though scarcely for firefighting. Since few drones can be remotely controlled and coordinated to operate simultaneously, their achievable fire-suppression capabilities are limited. Therefore, we propose the use of swarms of autonomous collaborative firefighting drones comprising a safe, robust, resilient and scalable system able to cope with uncertainty, errors, perturbations, and the failure or loss of a few units. A key enabling technology is the development of self-organisation algorithms that allow them to communicate and allocate tasks amongst themselves, plan their trajectories, and self-coordinate their flights to achieve the swarms objectives. Swarm Robotics studies how to design simple robots so that a desired collective behaviour emerges from the local interactions among a large number of them and with the environment. The design of the local interaction rules leading to the emergence of the desired systems behaviour is not trivial. Since decisions are autonomous, the emergent behaviour is hard to predict. Therefore, one of the main challenges is the design and formal verification of local interaction rules at the individual level so that the correct behaviour emerges at the system level with some degree of trustworthiness. At this stage, the self-organisation algorithm is a reactive rule-based approach based on the particle swarm algorithm, which in turn was inspired by social behaviour observed in nature. In the future, evolutionary robotics and reinforcement learning will be investigated to generate firefighting swarm behaviour automatically. Other enabling technologies developed in this project includes wildfire propagation modelling, multi-agent collision-avoidance algorithm, and the design of more efficient and lighter fire suppressants.