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FLOCKING TO ORBIT: SWARM ROBOTICS IN SPACE

Abstract

Around the turn of the century, scientific research began to proliferate on a novel approach to multi-robot systems called swarm robotics. This field, which takes inspiration from the behavior of social insects and other animals, is based on the concept that assigning local rules to simple robots can create emergent behaviors in a larger swarm system. By combining capabilities, an entire group of robots can coordinate and perform complex tasks in a more efficient and adaptable way than is possible with individual robots or centralized systems. The swarm vision of system architecture has become highly influential in recent years, with many new startups intending to leverage this technology for new applications. Swarm has even gained recognition in popular culture, with Disney films like *Big Hero 6* and *Ralph Breaks the Internet*, as well as TV shows like *Black Mirror*, all featuring swarm in their storytelling. Today, the private sector envisions a variety of government and commercial applications for swarm robotics, such as autonomous vehicles, 3D printing, and environmental mapping. Because space technology heavily depends on advancements in robotics, swarm applications will inevitably impact future space capabilities. Further, as space system design matures, constellations of small satellites and other innovations indicate a trend towards highly distributed and scalable systems for increased redundancy and resiliency in the hostile space environment. Swarm intuitively complements systems of this nature. To explore the implications of swarm robotics for future space architecture, we conducted a comprehensive study on the state of the art in swarm, with a particular focus on terrestrial applications proposed by private startups, and developed models for use cases in space. We also reviewed the literature on swarm robotics and space systems to identify conceptual relationships. Our findings indicate swarm technology can decrease operational costs for space missions by reducing the complexity of the individual spacecraft while enhancing the capability of the overall system. Moreover, swarm will enable greater flexibility in space systems by allowing them to achieve mission success regardless of the number of participating spacecraft. With these advantages in mind, we predict swarm robotics will impact multiple subfields of space technology, including robotic exploration, in-space manufacturing, spacecraft servicing, space transportation and logistics, and space domain awareness. In the future, we expect swarm to become a fundamental characteristic of space system architecture, radically altering our capacity to perform complex space missions.