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VISIBLE LIGHT COMMUNICATION ALGORITHMS FOR SMALL SPACECRAFT FORMATION FLYING AND SWARM CONTROL

Abstract

Radio Frequency (RF) has been used extensively in space for communications. However growing usage on Earth and increased traffic in space has led to RF congestion. Since RF is in high-demand, it makes practical sense to look at alternate options that can achieve high robustness and ease congestion. Visible Light Communication (VLC) is a form of optical communication that transmits messages at a high data rate using lighting cues. While existing VLC and localization algorithms are frequently used in indoor especially in terrestrial applications, they have yet to be used in space. We propose to use lighting cues algorithms to control formation flying and swarm control.

The concepts of satellite swarms and formation flying involve multiple satellites autonomously coordinating to accomplish various tasks. We propose using VLC algorithms to enable small satellites to coordinate their relative position and attitude to facilitate swarming and formation flying. LEDs on all sides of a satellite will blink at different frequencies and emit different wavelengths detected using cameras or light sensors on the target satellite. We embed messages in modulated light signals corresponding to the relative distance and position vector between the satellites, measured using ranging systems. The light sensors and cameras can also detect the relative position and attitude of the satellite using different wavelengths of light corresponding to a designated side of the satellite. Given the detected frequencies and wavelengths, the satellites can use propulsion or other attitude control systems to correct position and orientation misalignment.

In this paper, we discuss using VLC as a viable method of communication between small satellites for swarming and formation flying. We provide a quantitative and qualitative comparison in terms of mass, power, radiation (EMI), volume, bandwidth, data rates, and other parameters of VLC with other conventional communication systems in space. In addition, we explore the possibility of mimicking existing biological systems that use lighting cues to communicate in the deep sea. VLC faces challenges such as the requirement of a line of sight and susceptibility to interference due to external noise, with solar lighting being a source of interference. However, our work show that VLC modulation and demodulation-based algorithms such as Convolutional Neural Networks (CNN) and Deep Belief Networks (DBN) can be used effectively in close proximity operations along with other mitigation strategies to combat interference. These new concepts will be tested and demonstrated in simulation and laboratory testing.