Optimizing Satellite Swarms With Reinforcement Learning

Project Description:

Nearly half of the world's population lacks access to the Internet due to expensive infrastructure requirements. Traditional solutions, primarily satellite Internet, each have their own downsides including high latency, being affected by adverse weather, and general lack of coverage due to obstruction. However, through responsible innovation satellite swarms can be the catalyst for closing this digital divide and bring forth a type of global connectivity never seen before.

Satellite swarming behavior involves a group of satellites working together to accomplish a specific task such as data connection or transmission, all whilst continually orbiting the Earth. The success of satellite swarms depends on their ability to coordinate their actions and make decisions based on real-time information. Reinforcement learning is an approach that can help improve the performance of satellite swarms by enabling them to learn from their experiences and make better decisions, even helping them take initiative by plotting more efficient flight paths.

The goal of this project is to develop a reinforcement learning based solution for satellite swarming behavior. The solution will involve training a reinforcement learning agent to optimize the behavior of the satellite swarm in real-time. The agent will be trained using a combination of simulation and real-world data to learn the optimal behavior for the swarm.

Project Outline:

Problem Statement: Utilizing real-time performance metrics, we will evaluate the performance of the simulated satellite swarm based on the amount of data collected / transmitted along with adherence to guidelines involving orbital flight paths in comparison to a traditional satellite.

Simulation Environment: A simulation environment will be developed to simulate the behavior of the satellite swarm. The simulation environment will include realistic models of the satellites, their sensors, and their communication systems. The environment will be rendered using ModernGl textures with a PyGame window backend, each object being plotted along three coordinate axes (x - width, y - height, z - depth). In addition, once a satellite is in orbit, it will follow real-world conditions involving gravity and magnetic fields, be able to communicate with other satellites using a control system array, and accomplish specific programmed tasks.

Reinforcement Learning Agent: Reinforcement learning will be utilized for this simulation as satellite orbit is a given, we must simply reward or penalize certain behaviors within their control systems to optimize the parameters described in the problem statement. The agent using a defined neural network, like DDPG (Deep Deterministic Policy Gradient) optimizing reward and minimizing loss, will follow through a training loop where the satellite agents interact with their environment, collect data & experiences, and update the agent's neural network weights using the algorithm. Until we have converged till a good policy (max data transmission) we will continue to run through episodes, i.e. an episode is how long satellites may transmit data and stay in orbit. Once the agent is trained, likely using Keras & Tensorflow, we can evaluate its performance using metrics such as the success rate, average reward, or transmission over time.

Conclusion:

The expected outcome of the project is a reinforcement learning-based solution for satellite swarming behavior that improves the performance of the swarm and enables it to adapt to changing conditions. The solution will have applications in a range of industries, including space exploration, telecommunications, and environmental monitoring - hopefully generating interest on this new frontier of global communication

Citations:

Anicho, O., Charlesworth, P.B., Baicher, G.S. *et al.* Reinforcement learning versus swarm intelligence for autonomous multi-HAPS coordination. *SN Appl. Sci.* 3, 663 (2021). https://doi.org/10.1007/s42452-021-04658-6

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