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A MODEL FOR SATELLITE COLLISIONS

Abstract

With recent developments in the aerospace sector, such as the rise of mega-constellations, there has been a growing interest in understanding and modelling satellite collision risks. In the following, we propose a temporal network model for satellite interactions, which can help predict if and when events such as the Kessler Syndrome could happen.

In particular, we discuss the construction of a random geometric graph on a spherical shell, whose nodes represent satellites. This particular type of graph distributes a given number of nodes randomly on a spherical shell, which represents the Low Earth Orbit. Edges between nodes are then formed if satellites are close enough to interact.

Combined with SIS dynamics, these graphs can be used to represent satellite interactions in space. By assuming that satellites are in one of the two "functioning" or "broken" states, we can model collisions as an interaction of a broken satellite with a functioning one. Using standard network theory techniques, we are then able to find the most important nodes in the graph and study how these affect the long-time epidemic behaviour on the graph.

Next, we add temporal effects to the graph, with nodes moving through space in time. This models the dynamics of the satellites on their respective orbits. For simplicity, we impose elliptic movements of the nodes, assuming all satellites lie on elliptic orbits and observe how the dynamics change due to these temporal effects. Using temporal networks techniques, we are then able to study if and when satellites end up in an endemic state, which represents a Kessler syndrome effect.

Using this model, we can also efficiently investigate which methods would work best to prevent a Kessler syndrome event and use this simulation as a test-bed for future research in space collision avoidance.