Determining Space Debris Orbits for Collision Prediction Using Chaos Theory

Suryanarayanan, Aswath (School: Devi Academy Senior Secondary School)

On 10th February 2009, a satellite, Iridium-33, and a space debris, Cosmos-2251, unprecedentedly collided, producing more than 2000 cataloged space debris. Collisions like this and the ones that routinely occur in the Earth's orbit lead to an increase in the density of space debris which is a threat to the stability of the orbital environment. Beyond a critical density, the Kessler Syndrome, a cascading collision phenomenon, would occur. This can be prevented by collision prediction and debris removal. However, the current collision prediction models are not sufficiently accurate. As a novel approach, my research applies chaos theory to predict space debris collisions, close approaches and orbits with better accuracy. Chaos theory has its application in stock markets and weather prediction among others and brings some order from chaos. My research leverages the tools of chaos theory - Short Term Lyapunov exponent (LCE) and Lyapunov time (LT), which are applied to evaluate the final error of the simulated trajectory of the space object. My model, in a 5 step approach, predicts collisions and determines orbits with just three past Two Line Elements by considering the total uncertainty due to the perturbations in the LCE. Simulation using my model has produced a more accurate estimate of the miss distance in the Iridium-33 – Cosmos-2251 collision compared to NASA's SOCRATES model. For orbit propagation, my model obtained an average of 99.9906% accuracy, which is 38.8320% more accurate than NASA's SGP4 result with the same data. My project predicts collisions between space objects, reducing expensive collision avoidance maneuvers, identifying a clear path for a satellite after an avoidance maneuver, thus saving millions of dollars for the space organizations.

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