21st IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Modeling and Risk Analysis (2)

Author: Ms. Katharine Larsen
Embry-Riddle Aeronautical University, United States

Dr. Riccardo Bevilacqua
Embry-Riddle Aeronautical University, United States

USING MACHINE LEARNING TO PREDICT HYPERVELOCITY FRAGMENT PROPAGATION OF SPACE DEBRIS COLLISIONS

Abstract

The future of spaceflight is threatened by the increasing amount of space debris, especially in the near-Earth environment. To continue operations, accurate characterization of hypervelocity fragment propagation following collisions and explosions is imperative. While large debris particles can be tracked by current methods, small particles are often missed. This paper presents a method to estimate fragment fly-out properties, such as fragment, velocity, and mass distributions, using machine learning on terrestrial data and associated simulations representing space debris collisions. The fragmentation of high-velocity fragmentation can be modeled by terrestrial fragmentation tests, such as static detonations. Recently, stereoscopic imaging techniques have become an addition to static arena testing. Collecting data with this method provides position vector and mass information faster and more accurately than previous manual-collection methods. Additionally, there is limited space debris data of similar accuracy on individual fragments. Therefore, this imaging technique is used as the primary collection method for the research data. Machine learning methodologies are leveraged to predicted fragmentation fly-out from this static experimentation, in addition to simulations produced for the same system considering dynamic terminal conditions, such as impact velocity and orientation. Then, this technique can be directly applied to space debris collision data. First, gaussian mixture models (GMMs), fit via expectation maximization (EM), are used to model the probability distribution of the particles for each desired characteristic along various radii for a spherical surface of intersection. Once this training data is generated, regression techniques can be used to predict desired characteristics. In this paper, k-nearest neighbor (K-NN) regressors are used. Monte Carlo simulations are then used to validate the results, finding that this technique accurately estimates the total number of fragments expected to intersect with a given radius, along with the total fragment velocity and mass associated with that surface. This information can then be used to estimate the kinetic energy of the particle to classify the particle and avoid future debris collisions.