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GEODESIC INTERSECTION GRIDDING FOR GROUND RISK ASSESSMENT OF SPACE DEBRIS

Abstract

This paper reviews current gridding techniques for calculating ground risk from space debris. It also introduces a novel geodesic-based method designed to overcome limitations in traditional gridding approaches. Basic gridding methods employ latitude–longitude grids that produce non-uniform divisions and contain singularities at the poles. Another simple method involves projecting the curved surface onto a flat plane and subsequently re-projecting back onto the sphere. Although this flat-model conversion improves spatial uniformity in many cases, it also introduces singularities near the polar regions, where grid distortions become especially pronounced. Southern Launch, who operates a polar orbital launch complex, thus requires a more advanced griding method which is not affected by polar singularities and distortions.

In response to these requirements, the new approach leverages geodesics and their intersections to construct a two-dimensional grid defined by crossrange and downrange coordinates. By defining a 2D grid in crossrange and downrange coordinates, geodesics can be used to transform these coordinates back onto the globe, with no loss in spatial information. This is critical for accurately mapping the dispersion of debris and for the subsequent derivation of risk profiles using Kernel Density Estimation (KDE) techniques, which rely on consistent spatial resolution to generate precise probability density functions (PDFs) for ground and air risk.

The paper begins by conducting a thorough literature review of existing gridding techniques, discussing both their theoretical underpinnings and practical implementations in risk assessment scenarios. This review highlights the advantages and shortcomings of latitude–longitude grids and flat-model transformations, with particular emphasis on how these methods affect the reliability of KDE-derived risk profiles. Examples showing the downsides of these methods are developed using Southern Launch's MAGIC software, designed to create Range Safety Templates.

Following this review, the new geodesic method is presented in detail. The methodology section describes the process of transforming a 2D crossrange and downrange grid onto a globe representation, and the counter transformation. Example results are shown, demonstrating the benefits of the geodesic-based system compared to other methods. Ultimately, this research looks at contributing to advancing and increasing the fidelity of Flight Safety Assessments for space debris on the ground.