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Author: Mr. Tomoki Kuga
Tokyo Metropolitan University, Japan

Prof. Hirohisa Kojima
Tokyo Metropolitan University, Japan

SELF-POSITION ESTIMATION USING SHADOW OF TERRAIN FOR PRECISE PLANETARY LANDING

Abstract

Landing spacecraft on other planets depends more on autonomous navigation and landing control than on remote radio control from Earth, since lag times inherent in remote radio control over such large distances lead to excessive fuel consumption in altitude maintenance.

In previous planetary landings, acceptable target point distance errors were approximately 10 km. Errors of that magnitude are too large when the goal is to reach scientifically interesting areas in the vicinity of hazardous terrain, making it necessary to achieve precise landing within several hundred meters of the target point.

Planetary landing demands precise estimation of the self-position as the lander approaches the planet's surface. Current inertial guidance systems are not sufficiently precise; accumulated acceleration sensor integration errors are too great. A more precise lander self-position estimation method is required, and this is what is offered by terrain relative navigation (TRN) methods. TRN collates preliminary observed terrain data around the target point, along with terrain images taken by a lander's camera, and then estimates the position of the lander.

A TRN method using crater-based features detected from lunar surface images is being studied in Japan for application in the Moon Investigation by Small Lunar Lander (SLIM) project. This method is effective for landing in areas that have many craters, but cannot be used in areas where no craters exist. Furthermore, the number of craters captured in images during the descent phase is most likely not sufficient for precise self-position estimation, and therefore cannot be used to correct for navigation error. Thus, it is necessary to develop a new TRN method that can be used even in areas where no craters are present.

In this paper, we propose a new TRN method based on an edge extraction algorithm using the surface shading of terrain. This method selects feature points from shadow edges, calculates the relationship between arbitrary points and feature points, and compares that information with terrain data around the target point. It can then estimate the self-position of the lander through simple processing. It can be used during the descent phase for landing, even in areas without craters. The effectiveness of the proposed method is validated through numerical simulations, using images generated from a digital elevation model of simulated terrains.