Extended Abstract

Intelligent Landing Hazard Assessment and Avoidance for *Safe* Spacecraft Landing

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This paper presents a novel multi-sensor information fusion methodology for landing hazard assessment and avoidance. The focus of this research is to analyze hazard characteristics of a planetary surface using imagery data obtained in real-time during spacecraft orbit, descent, or landing. This information is used to enable a spacecraft to safely touchdown on a planetary surface during mission operations. The focus of our approach is on robust terrain analysis in which the terrain is analyzed using multiple sensors and the extracted terrain characteristics are combined to select safe landing sites for touchdown. The novelty of this method is the incorporation of the Terrain-Hazard Map, which represents the risk associated with landing on a planetary surface, and the Fuel Map, which discriminates between landing locations based on spacecraft fuel constraints. The hazard assessment and avoidance algorithm is explained in detail in this paper and computer simulation results are presented.

Introduction

Safe landing of a spacecraft on a planetary surface is of critical importance for the success of NASA exploration missions. The selection of an appropriate landing site for a spacecraft touchdown is therefore of fundamental significance. The landing site selection process is implemented in two stages. In the first phase, an off-line site selection process occurs in which mission engineers and scientists visually examine hundreds of pictures of potential sites obtained from previously acquired orbiter imagery. Based on this examination, the appropriate site is then selected by considering both engineering and science goal criteria. The site that ideally satisfies both objectives is then used to plan the spacecraft trajectory and landing profile.

After initial deployment, the spacecraft eventually arrives to its designated orbital coordinates. It then begins a quick descent to the planet's surface. During the descent phase, the spacecraft is required to detect and avoid hazards on the surface in order to ensure a safe landing. Current state-of-the-art research efforts [1-2] focus on utilizing LIDAR or optical sensors to extract hazard information. Although these efforts analyze the safety of the terrain based on roughness and slope characteristics, the recommendations from disparate sensors are not evaluated to determine failure points and there is no distinguishing factors used to discriminate between comparable safe landing sites.

To address these limitations, we have developed a methodology for on-board hazard assessment and avoidance to enable safe landing of a spacecraft. Based on terrain quality and the spacecraft fuel constraint, a real-time reasoning engine computes the optimum landing site, when the original site is not optimal from the safety points of view. This enables any necessary trajectory adjustments to occur in the thruster command sequence to minimize the risk to the spacecraft at touchdown.

Technical Overview

The approach adopted in this research effort is to emulate human reasoning logic in order to determine the optimum landing site for the spacecraft on a planetary surface. This process is accomplished using the following steps, as shown in Figure 1:

- Assess terrain hazards using image data extracted from the spacecraft sensor suite
- Combine hazard information retrieved from sensory data into a unified terrain-hazard map representation
- Employ a linguistic rule-based system for optimum landing site selection based on safety requirements
- Distinguish between comparable safe landing sites based on *reachability* calculated from the spacecraft fuel constraint

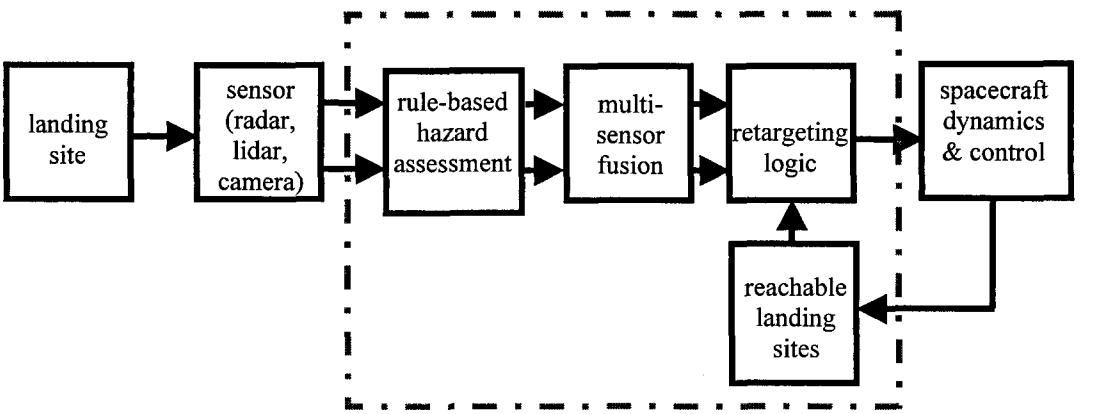

Figure 1: Process flow for hazard assessment and avoidance algorithm

Conclusion

The approach employed allows the system to be tolerant to imprecision in sensor measurements and uncertainty in data interpretations inherent in sensing and perception of landing sites. It provides the capability to capture the landing requirements expressed by mission engineers and scientists in plain English. And the approach is simple, has low computational demands, and is easily extendable to incorporate several site characteristics or to fuse data from multiple sensors. By utilizing this algorithmic approach, our research will significantly reduce mission costs and risk by ensuring spacecraft survivability during the landing process.

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References

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