HIGH PRECISION LANDING SITE MAPPING AND ROVER LOCALIZATION BY INTEGRATED BUNDLE ADJUSTMENT OF GROUND-BASED IMAGE DATA

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ABSTRACT

High precision topographic information from all available data is critical to many landing site geological and engineering applications. Meanwhile, precise navigation and localization of the rover is important for its safety, engineering and scientific objectives when it traverses the Martian surface. In order to support future long-range rover missions (for example, 1km traverse in the planned 2003 MER mission), high precision landing site mapping and rover localization are desirable.

At a landing site, for example Mars Pathfinder (MPF) landing site, the mapping accuracy using lander images depends on the distance from the lander to the mapped objects because the lander imager is stationary and the resolution becomes lower for areas far away from the lander. On the other hand, the rover images cover the landing site with a much higher and even resolution, especially in the rover operation area. Therefore, taking advantages of rover images will be very helpful for producing the best topographic information of the landing site and for rover navigation.

Supported by a NASA/JPL sponsored project "Mars Rover Localization Using Descent and Rover Imagery", we have developed algorithms and software for integrated bundle adjustment of orbiter, decent/lander, and rover images. At first, a three dimensional image network is built by linking all the orbital and ground-based images together using a vast amount of tie points identified and selected automatically or manually. Some distinctive features, such as mountain peaks and craters that can be observed from the orbital images, serve as relative controls for the adjustment. And then, the camera positions and attitudes of the rover images as well as all other images and 3D ground positions of all tie points can be obtained by a least squares adjustment. An incremental bundle adjustment model was also developed, which adjusts descent and rover images step by step, resulting in computational efficiency.

An innovative approach has been investigated for automatic feature extraction and tie point selection based on interesting point filtering and image matching techniques. The preliminary experiment showed that the approach works well for stereo images at individual camera stations. Extension to cross-station and between descent/lander and rover images will be tested.

Techniques of generating hierarchical DEM using descent and rover images were also developed for Mars landing site mapping and rover localization. Based on the improved image orientation parameters and DEM, orthophoto images and mosaics can also be produced.

In order to verify our algorithm and software, two field test were conducted in April 1999 and May 2000, respectively, at Silver Lake, CA. Based on the data various rover localization experiments were carried out. The rover localization accuracy has reached about 1m for a traverse length of 1km from the landing center, using descent and rover images by an integrated or incremental adjustment. The root mean square (RMS) errors of the ground coordinates of checkpoints are 0.195m, 0.211m and 0.429m in X, Y, and Z directions, respectively. The experiment results also show that if there is no descent images available (like MER mission), it is still feasible to localize the rover using rover images only and achieve the similar accuracy with more efforts in optimal traverse design and image network generation.

Currently, we are conducting bundle adjustment using MPF lander and rover images. It is expected that with the combined rover with lander images in one image network, the overall mapping and rover localization accuracy will be greatly improved. The latest result will be presented at the workshop.

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