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ESA ExoMars Rover PanCam Pre-launch Modeling and Accuracy Assessment for Localization and Topographic Mapping

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Abstract

The ExoMars Rover Mission is the flagship mission of the European Space Agency (ESA) Aurora Program. The ExoMars rover, highly mobile scientific platform, will carry a drill and a suite of instruments dedicated to exobiology and geochemistry research on Mars. As this rover will be expected to travel kilometers over the Martian surface [1], high-precision localization and topographic mapping will be critical for safe Martian surface operations, precise traverse path planning, and coordinated multidisciplinary scientific experiments. The design of the stereo imaging system planned for the ExoMars rover, the panoramic camera (PanCam), is vital to achieving a high level of precision in rover localization and topographic mapping. Quantitative error analysis of this system is being conducted in order to improve the system's design as well as increase scientists' awareness of the level of precision available, thus enabling them to make decisions with appropriate situational awareness. This paper presents the initial results from our error analysis of the ExoMars PanCam using an analytical approach.

1. Introduction

The ExoMars PanCam system will be used to support all the mapping requirements of the ExoMars rover. Therefore it is critical to assess the levels of localization and mapping accuracy attainable from PanCam data to aid the ExoMars design team to achieve the best overall design for the mission. Theoretically, mapping and localization accuracy is influenced by a number of factors including the length of the stereo system's hard baseline, the focal length, the pixel size, as well as the distances between adjacent rover sites. Two different approaches that consider all these influential factors have been analyzed. This approach is an error propagation model based on the incremental BA technique and error propagation theory.

2. Panoramic Camera System

The ExoMars PanCam imaging system consists of a pair of identical multispectral Wide-Angle Cameras (WAC) capable of producing panoramic imagery, along with a High-Resolution Camera (HRC) imaging system having higher resolution and much longer focal length, and capable ofproducing color imagery. Currently, ESA design requirements designate WAC field-of-view (FOV) as 34° and HRC FOV as 5° (subject to change) [2], [3]. The design of the HRC will allow for the magnification of selected targets (with respect to the wide-angle optics) as well as high-resolution imaging of far-distant, inaccessible locations.

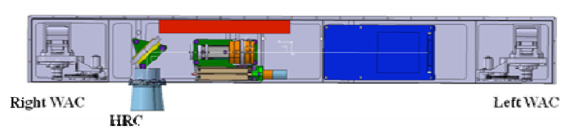

Figure 1. Preliminary configuration of the ExoMars PanCam imaging system (under development). Photo Credit: PRoVisG PanCam Team.

As shown in Figure 1, this imaging system is mounted on a crossbar attached to the rover mast at a height of approximately 1.5 m above the Martian surface.

3. Initial Pre-launch PanCam Modeling and Error Analysis Results

At this stage of quantitative error analysis of the PanCam system, research has been focused on modeling the WAC stereo pair. Efforts are ongoing for modeling the HRC to support the analysis about how the integration of HRC imagery improves the accuracy of the rover localization and the generated topographic products.

Rover localization and topographic mapping is achieved using a local image network created from panoramic imagery of the Martian surface generated at rover stopping points (stations), and navigation images obtained along the rover traverse paths. This local image network (Figure 2) forms the basis for automatic incremental bundle adjustment (BA), the fundamental technique routinely performed during rover operations for accurate localization and high-precision 3-D mapping [4].

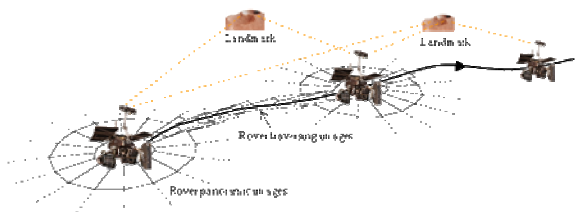

Figure 2. PanCam image network.

A rigorous mathematical model has been developed to estimate the level of accuracy that the incremental BA technique can achieve using the current ExoMars PanCam design. Based on photogrammetric principles and error propagation theory, this model allows us to theoretically analyze how the above-mentioned factors influence mapping and localization accuracy. In general, higher accuracy is found with longer stereo baselines, longer focal lengths, smaller pixel sizes, and larger numbers of tie points. The initial theoretical error analysis of these factors was conducted under the assumption that the tie points (landmarks) are evenly distributed between two rover stations. Figure 3 shows the results of the initial mapping accuracy analysis for two stations with varying traverse lengths using nine evenly distributed landmarks as tie points.

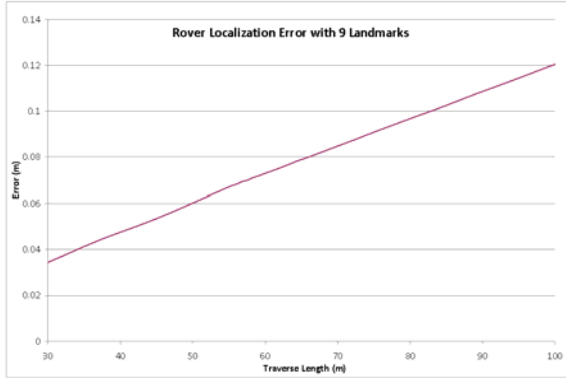

Figure 3. Localization error for two stations with varying traverse lengths.

In the next stage of this research, this initial two-site analysis will be extended to multiple sites to complete the error analysis of the incremental BA. Future research results will include the modeling of the HRC and integration of HRC imagery into the local image network to further support ExoMars PanCam design decisions. To further validate this model, we are building a prototype imaging system that mimics the ExoMars PanCam for experiments.

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