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

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ExoMars is the first flagship mission of the European Space Agency (ESA) Aurora Programme. The mobile scientific platform (rover) onboard, carrying a drill and a suite of instruments dedicated to exobiology and geochemistry research, will be able to travel a few kilometers over the Martian surface. High-precision rover localization and topographic mapping are critical for proactive traverse path planning and safe planetary surface operations. For such purposes, the ExoMars onboard Panoramic Camera system (PanCam) will acquire an imagery network providing vision information for photogrammetric algorithms to localize the rover and generate 3-D mapping products. Since the design of the PanCam will influence the localization and mapping accuracy, quantitative error analysis of the PanCam design will improve scientist's awareness of the achievable accuracy, and enable the PanCam design team to optimize the design for achieving higher localization and mapping accuracy.

This research aims at quantitatively assessing the mapping and localization accuracy of the PanCam system through theoretical and numerical simulation studies. Based on geometric cameral models, we have developed a rigorous mathematical model for estimating the accuracy that the incremental bundle adjustment (BA) technique is expected to achieve. This model allows us to theoretically analyze the mapping and localization accuracy that would be affected by various factors (length of stereo hard-baseline, focal length, and pixel size, etc.) using the photogrammetric principle and uncertainty propagation theory. At the same time, we also performed numerical simulation in accuracy analysis using Monte Carlo approach. Repeatedly adding a random Gaussian perturbation to simulated ExoMars imagery, we obtained error statistics of localization and mapping based on repetitive executions of BA. We set up a PanCam prototype and conducted experimental studies for comparing and evaluating the two developed approaches.