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Applications of the ExoMars 2020 PanCam Wide Angle Camera Simulator: Optimising Image Acquisition and Post-Processing

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Abstract

We describe how a simulation of the PanCam Wide Angle Cameras (WACs) can be used as a tool for validating and refining the algorithms and parameters involved in image acquisition and post-processing during the ExoMars 2020 rover mission. We demonstrate how the tool has been used to evaluate and optimise the PanCam WAC auto-exposure algorithm, and discuss on-going work towards validation and optimisation of the noise-removal and calibration pipelines.

1. Introduction

The stereo and multispectral image products of the PanCam [1] Wide Angle Cameras (WACs) will be used, in conjunction with the PanCam High-Resolution Camera (HRC), to produce geologic maps of the ExoMars 2020 Rover environment, to assist traverse planning, target selection for in-situ studies, and to support geological and atmospheric studies. The quantitative 3D and surface reflectance reconstructions required to meet these objectives benefit from high signal-to-noise ratio (SNR) images.

Once in operation, SNR for WAC images can be maximised by 3 key tasks: auto-exposure, for optimisation of the dynamic range used in each image; noise-removal; and calibration, against the PanCam Calibration Target and pre-flight characterisation measurements. Developing and validating the algorithms that perform these tasks with the PanCam flight hardware is an expensive process. Large quantities of images must be captured across the range of illumination, surface, and thermal conditions expected at the Mars surface environment, which are difficult, or not possible, to emulate in laboratory conditions.

We present a method for efficiently and autonomously evaluating and optimising trial algorithms, by utilising a full-system simulation of the WACs, as described by Stabbins et al [2], to support further validation with the flight hardware.

2. Simulated Algorithm Evaluation

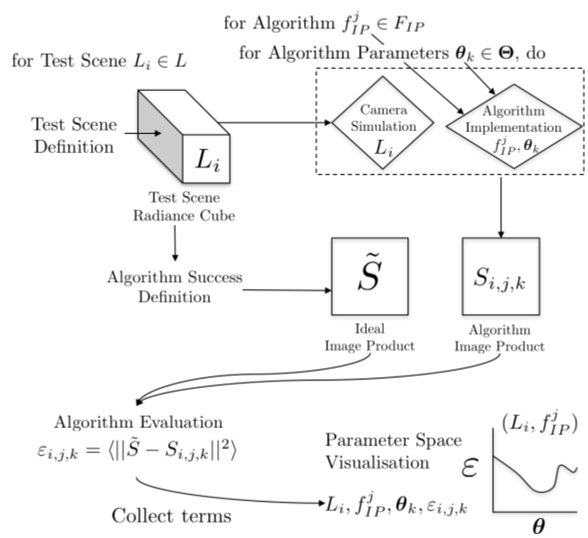

Figure 1 Method for evaluating image acquisition and post-processing algorithms

The general method is illustrated in figure 1. Ideal image products for a given task are defined and synthesized from an input test scene, as a hyperspectral radiance image cube. The parameter spaces of candidate algorithms are sampled, and the input test scenes processed according to the camera system simulation and implementation of the algorithm. Resultant images from the simulation are compared to the ideal examples via a cost-function. Cost-minimisation then guides the selection of optimal algorithms and parameter combinations.

3. Example: Auto-Exposure Evaluation and Optimisation

The PanCam WAC Auto-Exposure (AE) algorithm has the objective of finding the optimal exposure time of a given scene, for a selected filter. This is found by acquiring an image at an initial 'seed' exposure time, and then comparing the value of some statistical property of the image to a target value. The distance between the values is used to rescale the exposure time, until this distance is within a tolerance, or a maximum number of iterations are exceeded. The algorithm returns an image acquired at this final exposure time.

We have trialled the algorithm against 4 classes of scene composition (Solar, Horizon, Calibration Target, and Rock Target) and across radiance dynamic ranges scaled according to expectations derived from previous Mars surface measurements (e.g. [3]). The algorithm parameter space has been sampled comprehensively, including 2 statistical parameters over 128 values each (*Target* and *Outliers*) and the *seed* exposure parameter over 64 parameters, generating >1x10^6 images per scene.

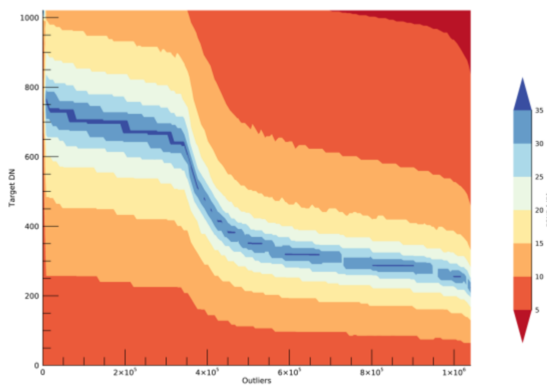

Figure 2 Example of Peak-SNR as a function of the 2 statistical parameters, *Target* and *Outliers*, for the Horizon test scene.

The most challenging part of the analysis is choosing a suitable representation of this high-volume dataset and high-dimensional cost-function, that provides information that can be used to optimise the algorithm. We pair the two statistical parameters, and produce 2D contour plots of the peak-SNR representation of the cost-function (e.g. figure 2). We have found from this representation that optimal values for these parameters lie on a function that can be derived from the original scene cumulative distribution function.

By comparing cost-function plots for the trialled scenes and radiance dynamic ranges, we found that no optimal solutions exist for all scene compositions, due to the wide diversity between, for example, a simple image of the solar disc and a more complex image of the PanCam Calibration Target.

4. Future Work

We have demonstrated how this method can evaluate an algorithm by generating and assessing over 1 million images, a task that would be unfeasible using flight hardware. We currently are leveraging the comprehensive noise simulation of the PanCam WAC Simulator to develop noise-removal algorithms, a less subjective task. This is performed by passing a given scene through the simulator with all noise functions disabled, and using the resultant image as our ideal image product. Similarly, we can tune calibration algorithms by comparing derived radiometric images to the input scene radiance cubes.

Once these key algorithms are refined, we can deploy this complete image chain simulation on simulated scientific observations, allowing for rigourous confidence limits to set on noise-sensitive observations.

Acknowledgements

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References

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