On-Board Image Processing and Computer Vision Techniques on Low-Cost Consumer Electronics for Vegetation Density Mapping and Other Experiments

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***Abstract*—Advanced on-board image processing is a foundational component of a wide range of future space science and Earth observation missions. Extending these techniques to include computer vision opens the door to even more opportunities for science. It is critical to develop these techniques on low-cost, consumer hardware platforms so that the missions need not require expensive, specialized systems for every experiment. Demonstrating these systems are themselves opportunities for science as well.**

I. Introduction

Image processing has long been a critical element of Earth observation and space science. In recent years, the capabilities of inexpensive consumer electronics and computers have reached a point where advanced image processing can be performed on-board with lightweight, low-power computers. This has opened the door for low-cost, rapid development experiment payloads and platforms such as high altitude balloons, drones, and small satellites. Usually these platforms have limited communications bandwidth, so on-board processing may be used to significantly reduce the amount of data transferred back to ground without losing the information that the images contain.

Computer vision (CV) is defined as the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images. CV is the realm between image processing and computer science where useful information is identified, extracted, and interpreted from images without human input. In addition to edge detection and other transforms applied to the pixel arrays directly, deeper and more abstract algorithms to interpret the contents of the images continue to mature in the field of machine learning. These algorithms are trained, or iteratively tuned with a large set of data, to classify objects or cluster multivariate data from an arbitrary set of inputs.

Naturally, any implementation of image processing or CV for space science must be tested in a flight setting. As this technology is developed, all tests are themselves opportunities for science. This Project Definition Document considers the logistics of this development in addition to discussing a number of experiments that may be conducted as tests or end-user applications of on-board image processing and computer vision with low-cost consumer electronics.

II. Primary Objective

The ideal result of developing robust image processing and computer vision techniques on flight electronics is a payload module for a high altitude balloon, small satellite or other flight system which is capable of reducing a video or image stream into a stream of processed useful information which can be relayed back to a ground station or efficiently saved to system memory.

While it is obvious that more powerful (and more expensive) electronics are capable of more advanced processing, the goal of this project is to push the limits of what entry-level hardware capabilities. In this way, software development takes the lead over hardware development. Since software can be reused between flights, loss of mission is not critical with low-cost flight electronics.

III. Secondary Objectives

Second to generalized platform development for an imaging and computer vision payload module is the science that payload would actually conduct. Every flight is a new opportunity to collect data, perform an experiment, or demonstrate new technology. Every module test will have a science goal in addition to any technology advancement goals. Specific experiment ideas are discussed in section VII.

IV. Benefit to SPEX

In addition to cultivating computer vision and image processing knowledge within SPEX, this approach favors clever and innovative solutions to squeeze every ounce out of inexpensive consumer hardware. By pushing the capabilities of these entry-level electronics, SPEX gains the most technological and science value possible. Computer-on-a-chip boards like Raspberry Pi are well-documented online and skills earned by SPEX members developing for this platform are easily applied to other projects that may also use this platform for computation.

A. Mindset

The mindset for development is to drive the hardware platform, software techniques, and science goals to the limit. Each experiment and every flight should aim to demonstrate a new technique and should have a strong science objective.

B. Traceability

GitHub shall be used for version control and issue tracking for software development. All library dependencies shall be documented.

C. Accessibility

The possibilities for scientific experiments with computer vision and image progessing are virtually limitless, and so are the opportunities for advancing knowledge within SPEX in imaging science. There are as many experiments accessible to beginners as there are available to experience imaging scientists.

In terms of software, computer vision and image processing requires a moderate familiarity in one of several computer languages, i.e. Python, and interfacing with hardware such as Raspberry Pi.

V. Implementation

A. Deliverables

B. Milestones

VI. Externalities

A. Prerequisite Skills

B. Funding Requirements

Since the premise of this project is developing robust systems on low-cost consumer electronics, funding requirements are marginal compared to other hardware-centric projects and missions. For example, a Raspberry Pi 3, camera module, SD memory card, and barrty pack can be purchased for about $100, and the hardware may be reused in almost any other SPEX project.

C. Faculty Support

Imaging and image processing experiments provide fertile ground for building a relationship between SPEX and the Carlson Center for Imaging Science, Center for Detectors, and Future Photon Initiative. Computer vision development poses an opportunity for SPEX to continue to network within the Golisano Center for Computing and Information Sciences. And, of course, all of the objectives of this project are directly applicable to space science and Earth observation, further building SPEX's mission of space exploration research.

D. Long-Term Vision

VII. Applications and Experiments

A. WUAP: where u at plants?

Vegetation density and NDVI. Mapping density with gps data.

B. WTFbiome: Wayfinding TransFormations and Biome identification

scene (biome) identification. morphological transformations to apply images to spatial coordinates.

C. SUP: Stereo groUnd mapping and Photometry

stereo 3d ground mapping and photometry.

D. PIP: Passive Instrument Payload

as an instrument: horizon detection. star tracking.

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