MAZE: A Testbed Unit for the Mars 2020 Mastcam-Z Stereoscopic Multispectral Investigation

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Abstract

One of seven scientific instruments on NASA's Mars 2020 rover payload, Mastcam-Z is a pair of multispectral, stereoscopic CCD imagers that will reside on the rover's Remote Sensing Mast. MAZE (**M**astcam-Z **A**SU **Z**oom **E**mulator) is a Mastcam-Z testbed unit designed by its science team members. Utilizing a pair of commercial off-the-shelf cameras, a pan/tilt unit (PTU), microcomputer, IMU, and Li-ion batteries, MAZE is able to operate in both lab and field imaging campaigns (Fig. 1). A suite of software tools allows the team to command pan/tilt pointing, capture stereo images, generate Planetary Data System (PDS) compliant image products, and perform camera calibrations. The goal of the emulator is to understand what data, analysis tools, and processes the team needs to implement during actual operations on Mars.

1. Introduction

Early in the mission, scientists on the Mastcam-Z team identified the need for a testbed unit that would allow us to create and interact with image products prior to launch. Such products would allow the team to create and evaluate tools being developed for science and tactical rover operations. Through this interaction, the science team aims to have a better understanding of what is desired from the products returned by MAZE as well as which analysis tools provided by team members will most benefit the team and mission during science and tactical operations.

2. Hardware Design

MAZE uses two Canon EOS D60 digital cameras with manual zoom lenses capable of focal lengths comparable to that of Mastcam-Z [1]. 3D printed toed-in angle mounts are used to interface each camera to a metal bar, which mounts the cameras to the PTU (see Fig. 2). The camera placement and use of toe-in angle allow the cameras to mimic the approximate orientation of the actual Mastcam-Z cameras when they are mounted on the rover. During operation the cameras, an IMU that collects GPS and movement telemetry, and the PTU, all establish a connection with a microcomputer via USB and an Ethernet network. The user then commands the system via laptop. A hard case, lithium ion battery packs and transport cart allow the system to become power independent and capable of performing field imaging campaigns for 8+ hours at a single time (see Figs. 1 and 2).

3. Planetary Data System Products

NASA's Planetary Data System manages the long-term archiving of pre-flight and in-flight data products from Mastcam-Z, including a specific file and label structure defined for all data products. To identify what meta-data will be important during mission operations the Mastcam-Z science team runs images taken by MAZE through it's software library to create flight-like PDS3 and PDS4 image products. These test products allow us to confirm that the format and kinds of data currently developed work with team software tools and align with pre-defined PDS fomat definitions.

4. Camera Calibration

Investigation goals set out in [1] and other results derived from Mastcam-Z data require the camera system to be accurately geometrically calibrated to provide the science and operations teams with terrain meshes, digital terrain models (DTMs), and other dimensionally accurate products. Such products are created using a camera model to represent the transformation from the object domain (field site) to the image domain (camera sensor) [*e.g.,* 2]. The camera model largely used by NASA for planetary exploration is the CAHVOR model. The CAHVOR model represents a set of vectors and parameters known about the specific camera to make this transformation from the object to image domain. Using specific targets and OpenCV software, MAZE can define a pinhole camera model (also called a

photogrammetric model) for geometric transformations. Python code was written to take this pinhole camera model and convert to the CAHVOR model using the equations provided in [2].

Like the test PDS products, MAZE's camera calibration and imaging capability has assisted in the evaluation of image processing tools used by the Mastcam-Z team. To identify which tools best produce the necessary products for science and tactical operations, so-called "Bake-Off" data sets (comparing performance among multiple tools) are made by converting MAZE mosaic image sequences taken in the field (see Fig. 1) into PDS products. These products are then made available to Co-Investigators to run through their specific software. Once completed their results are compared to determine which tools are best suited for use during the mission. Comparison parameters include: run time, accuracy, and file size.

5. Figures

***Figure 1**: Team members performing field imaging campaign in Tempe, Arizona, USA.*

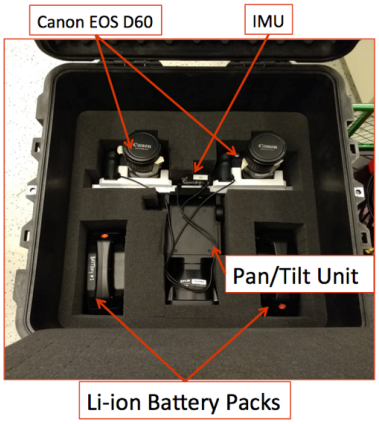

***Figure 2**: Top of MAZE in hard case*

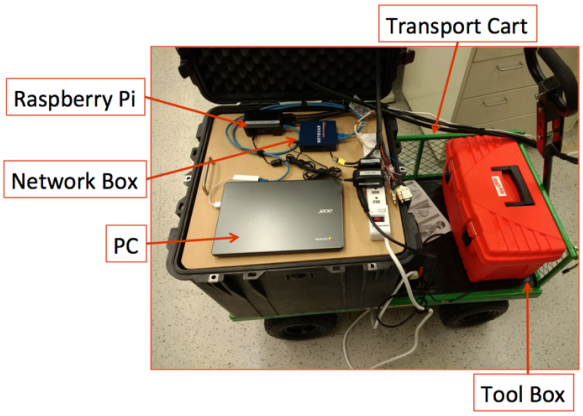

***Figure 3:** MAZE electronics and transport cart.*

Summary

The Mastcam-Z ASU Zoom Emulator (MAZE) testbed unit is an off-the-shelf stereo camera system created by the Mastcam-Z science team for pre-flight field and laboratory testing relevant to the the Mastcam-Z stereoscopic multispectral science instrument on NASA's Mars 2020 rover. It is being used to assist in image product validation, camera calibration, and software tool analysis prior to launch and landing of NASA's Mars 2020 rover.

Acknowledgements

The authors acknowledge Bob Deen at JPL/MIPL for general wisdom and PDS validation assistance, and the Mastcam-Z science team for their participation and involvement in MAZE imaging campaigns.

References

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