INCREASING HIGH DYNAMIC RANGE FOR PLANETARY WHOLE-SKY IMAGERS.

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Introduction: Currently, only the Mars Science Laboratory [1] and InSight Lander [2] are collecting surface-based data concerning the Martian atmosphere. As a result, there is a relative scarcity of Martian climatic data, and General Circulation Models (GCMs) of Mars have a fairly low resolution and cannot be adequately validated. It has been suggested that between 15 and 20 surface weather stations are needed in order to characterize the full, time-varying structure of global circulation [3].

The goal of the Mars Atmospheric Panoramic camera and Laser Experiment (MAPLE) is to develop a relatively compact and efficient atmospheric monitoring instrument which can be deployed on future landers. The MAPLE instrument will measure the size distributions of near-surface aerosols, measure dust optical depths, determine ice crystal habit and act as a whole-sky imager, tracking clouds and their morphologies [4].

One challenge of whole-sky imaging is that the inclusion of the sun in frame leads to oversaturation of the circumsolar pixels, leaving other regions of the image underexposed. This can make it difficult to detect atmospheric features such as clouds when the sun is in frame. This project aims to create a high dynamic range (HDR) imager using a digital micromirror device (DMD) for potential use with the MAPLE instrument or other planetary atmospheric imagers.

High Dynamic Range Imaging and the Digital Micromirror Device: Current methods to increase the dynamic range of an image include physical sun blocking mechanisms and post-processing of images. For instance, the Mars 2020 Mars Environmental Dynamics Analyzer (MEDA) includes a coating on the CCD window near the noon solar angle and a high opacity ring which is able to block the sun for a few minutes per sol [5]. A mechanical sun-tracking blocker can allow the much dimmer surroundings to be resolved, however the blocker itself and its support structure can occlude other parts of the image [6].

One digital HDR technique is to take multiple versions of the same image at different exposures, which are then combined into a single image [7]. This method, however, does not provide an adequate dynamic range for imaging the Martian sky, where the sun may have a difference in radiance of 10^9 [8]. Making use of a DMD could provide the needed dynamic range, and indeed a DMD-based imaging system has been shown to have a theoretical range of over $1:10^{10}$ [9].

A DMD consists of an array of micromirrors which can be individually rotated in order to direct light towards or away from an observer, in this case a CCD. If each micromirror covers one pixel in the image, it is possible to turn 'off' oversaturated pixels and allow the remainder of the image to be sent to the CCD [10].

Ongoing Work: A setup for the HDR imager is currently under construction, utilizing a single CCD camera and the DMD. There are a few basic modes for the DMD. The 'flat' state exists when the DMD is unpowered and all micromirrors are at an angle of 0°. In the 'all on' state, the image is reflected to the DMD unchanged, with each micromirror tilted in the 'on' direction. The final state uses a mixture of micromirrors in the 'on' and 'off' directions, with the micromirrors covering the oversaturated region(s). This final state is what will allow us to increase the dynamic range by blocking a light source such as the sun.

The current setup consists of the DMD, a lens for the incoming image and the CCD. The positions of the lens and CCD can be moved in two horizontal directions, and the DMD can be rotated and moved vertically, allowing for precise positioning in order to center the image when the DMD is powered.

Figure 1 – The current imager setup. The DMD is not shown attached.

Another possible configuration of the setup involves the use of a second CCD which can capture the pixels which have been turned ‘off’, allowing the entirety of the image to be captured but maintaining the HDR that allows us to see fainter features, which can be used to determine column optical depth measurements with a neutral density filter.

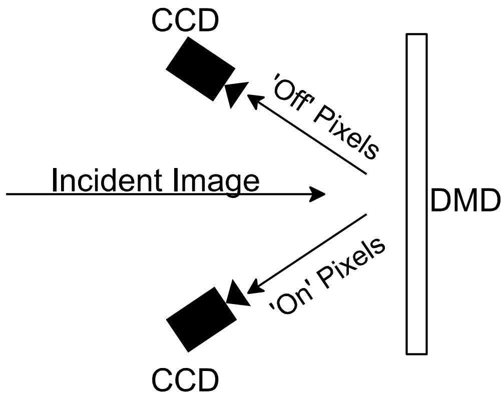

Figure 2 – Diagram illustrating a possible alternate configuration of the imager setup.

Testing of the current setup will be done in the lab using a lamp as a light source, and will then move to testing under various weather conditions at York University.

By the time of the conference, the single-CCD setup is expected to be completed and testing with a lab-based illumination source begun. This will help to determine the dynamic range of the imager. In addition, it is possible that there will be solar images captured with the setup in order to determine if it effectively increases dynamic range of atmospheric images.

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