

A Programmable Hyperspectral Imager for Space Applications

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Hyperspectral imaging is a valuable tool for earth observation, with a broad range of applications. For the large majority of satellite-based hyperspectral imagers, the 3 dimensional hyperspectral cube is reconstructed from multiple acquisitions of a 2D detector array. Most of these imagers have a 1D field-of-view so the detector array acquires the spatial data in one direction and the spectral components in the other [1]. The satellite movement is used to acquire the second spatial dimension of the hyperspectral cube. This method of acquisition is straightforward but the light flux received by the detector is low due to the entrance slit defining the field-of-view.

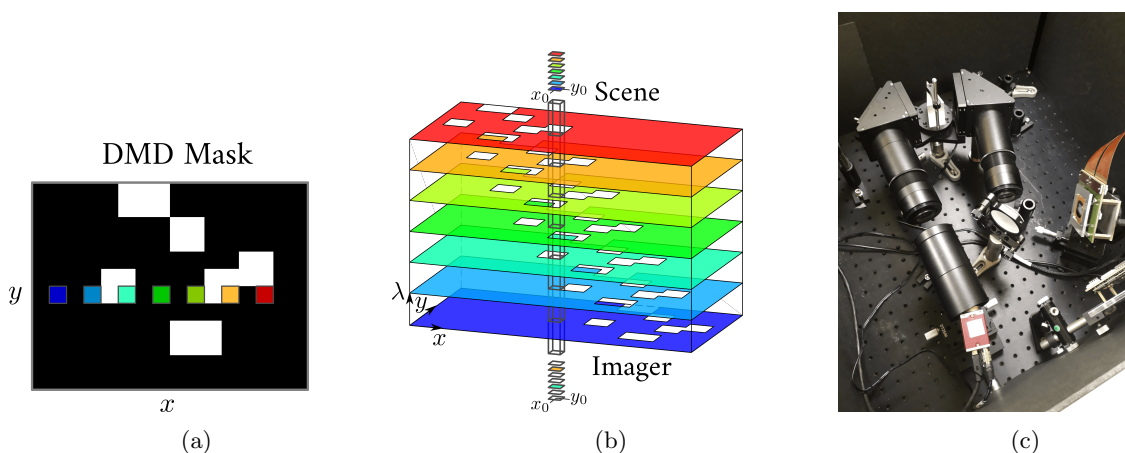


Figure 1: a) The spectral components of a unique spatial point imaged along a DMD mask line. The state of the micromirrors (ON/OFF) on this line defines the filtered components for this spatial point b) The colocalization of the spectral components on the imager is assured by the system. A spectral component of the spatial point (x_0, y_0) in the scene is either blocked or imaged at (x_0, y_0) on the imager (depending on the state of the corresponding micromirror) c) Prototype dual-disperser hyperspectral imager

Hyperspectral imagers based on digital micro-mirror devices (DMD) have gained traction recently. DMDs are fast, reconfigurable and have no moving parts, making them ideal for space applications. With these characteristics, DMDs are key components for developing specific algorithms customized to the optical system. For a dual disperser architecture with a 2D field-of-view, one measures a mixture of spatio-spectral information on the detector, whose content is controlled by the DMD [2] (refer to figure 1a) and 1b)). In this system, the DMD acts as a spatio-spectral filter that can be easily reconfigured. For example, by employing coded masks such as Hadamard matrices on the DMD, the signal-to-noise ratio can be improved, exploiting the multiplexing advantage [3].

Furthermore, we propose that by making reasonable assumptions on the properties of the hyperspectral datacube, the number of acquisitions itself can be greatly diminished. One such assumption is that many of the adjacent pixels in the 2D image share a similar spectra. This regularity assumption (RA) reduces the required number of acquisitions to much less than the number of bands, and has been shown to be valid for

a large range of hyperspectral images [4]. This RA-based acquisition scheme exploits the redundancy in the data to solve an under-determined system of equations.

We have developed a prototype (cf. figure 1c)) and implemented this RA scheme. The prototype operates in the region 400-700nm, with more than 100 spectral bands, and 2048x2048 spatial pixels. The DMD allows programmable control over the spatio-spectral filtering, and allows us to test a variety of acquisition schemes.

Initial results are promising; compared to a straightforward slit scan, the RA acquisition scheme has an improved SNR with only 5 acquisitions, and the exposure time was 30 times shorter.

The prototype has been built for use in laboratory conditions, to test acquisition schemes. However, to evaluate the performance gains of the system compared to classic pushbroom hyperspectral satellite imagers, a dimensioning model of the system has been developed. Considering structural and performance constraints, it enables the exploration of multiple optical architectures corresponding to given acquisition schemes and algorithms.

Our current model suggests that the reduced exposure time enabled by both the architecture and the acquisition scheme enables acquisitions that are fast enough to limit motion blur for a given spatial resolution. By observing a scene that is a smaller in the along track direction than the field-of-view and with a synchronization between the detector and the satellite movement, multiple acquisitions of the same scene could be taken in one satellite pass. By doing so, a hyperspectral cube with high spatial and spectral resolution can be reconstructed.

References

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