

A DMD (Digital Micro-Mirror Device) Based Multi-Object Quasi-Imaging Spectrometer

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Abstract

In order to increase flexibility in spectral measurements performed by a point detector spectrometer, we are using digital micro-mirror devices (DMD) to selectively both illuminate and pick out regions of interest from a scene. The goal is to make a robust, quasi-imaging spectrometer and reduce the effects of scattered light from the background and nearby objects.

1. Introduction

For designing an optimal setup for a spectral measurement of a multi-object scene, a series of choices has to be made. Thorough analysis of the measurement situation unveils needs for spatial resolution, spectral resolution and wavelength band of interest and so forth. The solution might be a scanning point measurement, or some kind of imaging spectrometer, often including a dispersive element, a camera, and a scanning motion either using a mirror device (for example a DMD) or moving the sample. The latter is time consuming.

A spectral reflectance system is suggested (in Figure 1) which makes use of a point measuring spectrometer, a camera and two DMDs. This ensures that both the illuminated areas and the imaged regions are fully programmable.

The system is spectrally quasi-imaging in the sense that it can be adjusted to measure the reflectance from arbitrary regions of interest. In addition it will be possible to do multi-object spectroscopy by carefully designing a mask that allows several spectrally different objects in the scene to be rapidly measured in sequence.

We will focus on spectral measurements in the visual and near-infrared part of the spectrum, as there are several applications in this wavelength region where such a system is of interest.

1.1. Related Work

The use of DMDs for spectral measurements have been described earlier, but for other measurement strategies than the one presented here.

Several groups have used micro-mirrors to select specific wavelengths from a rainbow light source [1, 2, 3].

Sarvotham et al. [4] are using the DMD to build up an image using one single pixel photo detector. This enables them to image wavelengths from the scene that are not possible to image using present CCD or CMOS cameras.

DMDs have also been used in spectral imaging, where the regions to be measured are selected using a line imaging spectrometer. Kearney et al. have characterized the DMD's optical properties for this use in [5] and in [6] they describe how this can be implemented and used to make a spatial and spectral hypercube and how to adjust the integration time to avoid sensor saturation.

Nayar et al. [7] used a DMD in front of an imaging device for doing programmable imaging in order to switch the light off for pixels that have been saturated, resulting in an image with increased dynamic range.

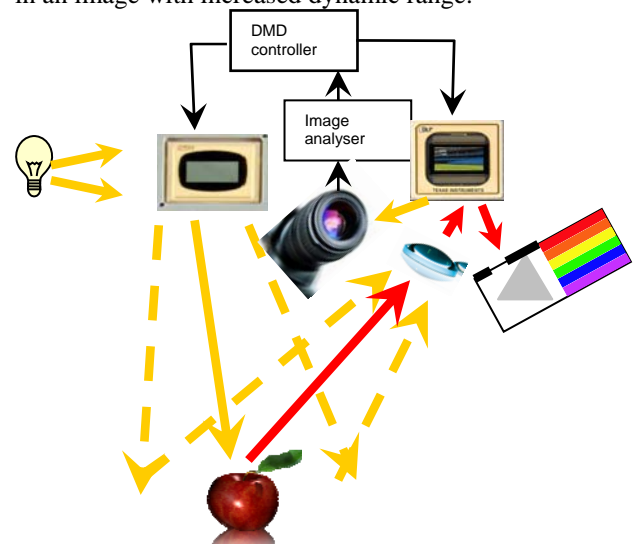


Figure 1: Schematic overview of the concept idea. The scene is illuminated and imaged onto a camera (via two DMDs). Based on image analysis, the region of interest is located, here the red apple. A mask is generated for the illumination DMD to ensure that only the apple is illuminated, avoiding the background and the green leaf. The detection DMD picks up only the light reflected from the apple and this light is projected onto the entrance aperture of the spectrometer.

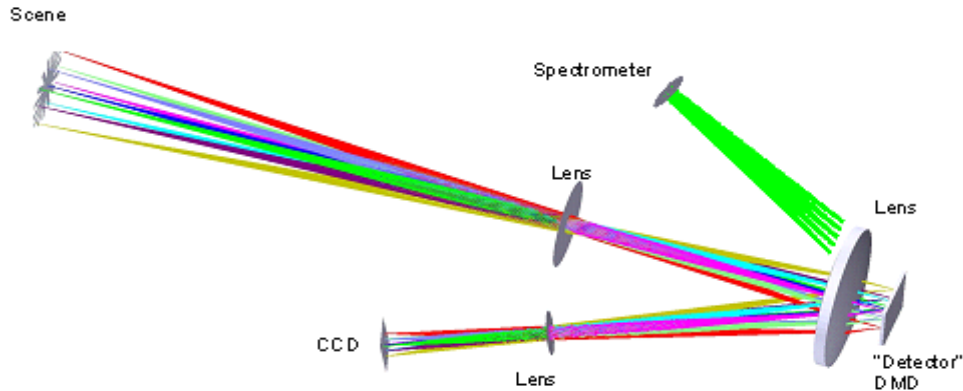


Figure 2: Zemax® raytrace of optics for the detection DMD. Light from the scene (top left corner) is imaged onto the DMD. Light from ‘on state’ mirrors in the DMD is reflected and imaged on the camera chip. Light from ‘off state’ mirrors in the DMD is reflected to the entrance aperture of the spectrometer. The scene is imaged on the DMD its ‘flat state’.

2. Setup and Methodology

The whole scene is first illuminated, and imaged by the camera, with all mirrors in both DMDs set to ‘on state’. Image analysis locates the object of interest. Second a binary mask based on analysis of the image is set on the illuminating DMD, so only the sample is illuminated. Scattering from adjacent objects and background influence is thereby avoided. A second binary image is set on the detection DMD; directing light from the object to the spectrometer. The spectral reflectance of the object of interest is measured in one shot without further scanning. The system has a dynamic spatial resolution, and can measure the reflectance from objects of arbitrary shape.

This configuration can also be used as a fringe projection system doing 3D measurements

Using a point measuring grating spectrometer makes the system easy to align and calibrate. It is inexpensive compared to an imaging spectrometer of high quality. The time used per measurement is reduced since no scene scanning is needed. We also achieve flexibility in adjusting the spectrometer’s integration time to the sample’s size and its reflectivity.

In Figure 2 we have suggested a design for the detecting side of the system. Software for synchronizing illumination, triggering of two DMDs, camera and spectrometer is under development

3. Further Work

This system will be characterized in terms of achievable spectral and spatial resolution, signal-to-noise ratio and measurement time. Various test objects will be used for this purpose, e.g. fruit placed on different backgrounds.

For the system to be useful, measurement time is important. Fast measurement is dependent on time spent on image analysis, generation of masks for illumination

and detection, sending masks to the DMDs, integration time in the spectrometer, and analysis of the spectral data.

The design in Figure 2 will be further evaluated, assembled and integrated together with an illumination module consisting of a halogen lamp, a mixing rod, the DMD and a projection lens. To collect as much light as needed, fast lenses are preferred, and these tend to be spacious. Measurement time, geometry and resolution (both spatial and spectral) must be balanced.

Image analysis using 2D and 3D must be implemented to select the regions of interest.

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