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Adaptive, Hyperspectral Imager: Design, Modeling, and Control

Scot McGregor^{1,2}, Antoine Monmayrant^{1,2}, Simon Lacroix^{1,2}

¹ CNRS, LAAS, 7 avenue du colonel Roche, F-31400 Toulouse, France

² Univ de Toulouse, LAAS, F-31400 Toulouse, France

antoine.monmayrant@laas.fr

An adaptive, hyperspectral imager is presented. We propose a system with easily adaptable spectral resolution, adjustable acquisition time, and high spatial resolution which is independent of spectral resolution. The system yields the possibility to define a variety of acquisition schemes, and in particular near snapshot acquisitions that may be used to measure the spectral content of given (or automatically detected) regions of interest. The proposed system is modelled, simulated, and experimentally demonstrated. Measurement techniques are proposed for near snapshot acquisition of spectral data as well as video rate acquisition of rapidly adjustable, monochromatic images.

Hyperspectral imaging, that is the measurement of many spectral components for each point of an image has become a key technique in many fields of research and industry [1]. It usually relies on a scanning process to acquire the 3D hyperspectral cube using 2D CCD or CMOS imagers. Novel methods based on co-design allow snapshot hyperspectral imaging [2, 3]. They rely on sophisticated optical setups coupled to complex reconstruction algorithms with fixed trade-offs between spatial, spectral and temporal resolutions. Moreover, careful and detailed calibrations are compulsory for these algorithms to converge.

This contribution presents a dual-disperser setup similar to what was proposed in [4] but with a programmable mask (Fig.1) and associated simple algorithms that alleviate the fixed trade-offs, calibration and computational complexity issues to propose an adaptative hyperspectral imager. This setup (Fig.1(a)) consists of a modified "4-f line" (made of gratings and lenses) with a programmable spatial light modulator (SLM). It acts on the final image as a programmable local spectral filter and in particular the spatial features of the final image (resolution, position of the different components) are totally independent from the programmed spectral features. In particular all the spectral components on a line in the hyperspectral cube are all colocated on the same position on the final image. This colocation property together with the extremely simple relation between the SLM pattern and the filtered final image allows to perform fast hyperspectral acquisition with straightforward reconstruction, allows direct access to the unfiltered image and to design near snapshot hyperspectral imaging

where several region of interest in the image are fully characterized in parallel. This contribution will provide a simplified analysis to grasp the key benefits of this approach, a detailed model based on gaussian optics to describe and simulate realistic performances of such a device. It will also show a first experimental demonstration with a prototype (see Fig.1(b)) that uses a folded geometry with a reflective grating and a digital micromirror device (DMD) as a SLM. Experimental demonstration of snapshot hyperspectral imaging of several region of interest will also be presented. Last, extension of the method to provide video rate, random accessible monochromatic spectral imaging will be discussed.

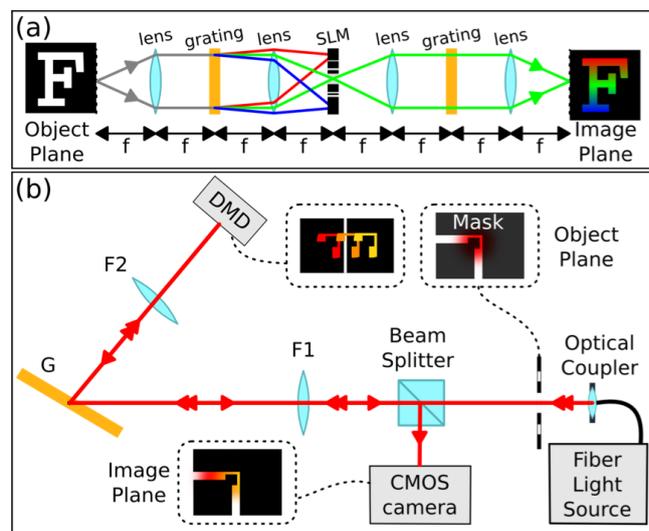


Fig. 1 : (a) Schematic of an adaptive hyperspectral imager ; (b) Prototype based on reflective grating (G) and digital micromirror device (DMD).

The adaptability and simplicity of this new hyperspectral imager paves the way to novel applications, particularly in the field of embedded hyperspectral imaging where resources are limited and real time access to the reconstructed data is key.

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