Hyperspectral Imaging using a Commercial Light-field Camera

R. P. Stanley, A. Chebira, A. Ghasemi, L. A. Dunbar, E. Franzi

Snapshot hyperspectral imaging allows the collection of both spectral and spatial information in a single exposure. A common solution is to create a huge array of filters on the detector. We apply the approach of Levoy & Horstmeyer to build a hyperspectral camera based on a Lytro™ commercial light field camera. We show reconstructed hyperspectral images with 9 spectral channels and show how this can be increased to achieve 81 spectral channels in a single snapshot.

Hyperspectral imaging allows the collection of spectral information from across the EM spectrum while still retaining the spatial information. Typically, a hyperspectral camera will create a 3D cube of images, wherein the spectral information for each location or pixel on the image is depicted. This modality is naturally fitted for objects/materials identification or detection processes, and has encountered a large success in the agriculture and food industries to name a few.

In snapshot spectral imaging, the 3D cube of images is taken in one shot, with the advantage that dynamic scenes can be analyzed. The simplest way to make a hyperspectral camera is to put an array of wavelength filters on the detector and then integrate this detector with standard camera objectives [1]. The technical challenge is to make arrays of N wavelength filters and repeat this sequence up to 100'000 times across the detector array, where each individual filter is matched to the pixel size and can be as small as a few microns.

In this work, we generate the same effect with just one N wavelength filter array, which is then multiplied and imaged optically onto the detector to achieve the same effective filter array. This was first outlined by Levoy and Horstmeyer [2,3] using microlens arrays in a light-field camera (Plenoptics 1.0). Instead of building our own light-field camera, we used an existing commercial camera, Lytro™ [4].

There were three major challenges in this work. The first was to design an optical system that would be compatible with the Lytro camera. Second, to override the camera hardware and firmware to get access to the raw data, and third, to reorganise the information into different spectral channels.

The design we developed is based on a telecentric system. This is a system without parallax so that the size of an object does not depend on its distance (as long as it falls in the depth of field of the camera). Telecentric systems are well suited to the type of light-field system we want to build.

Our design was implemented in the lab, using a linear variable wavelength filter as the core wavelength selecting element. The wavelength transmitted by the filter depends on the position. The uniqueness of the light-filed camera system is that it converts this spatial variation into angle information, which is then extracted at the detector using a microlens array.

Adapting the Lytro camera was not trivial and required a careful disassembly. The data was extracted using an open source Matlab toolbox [5] that was adapted for our needs.

The system was tested using a colour checker card and a white light source. The results of the data before and after analysis can be seen in Figures 1 & 2. Figure 1, is the raw data as read from the Lytro camera, processed with a demosaic filter. After using the Matlab toolbox the multispectral mosaic can be displayed (see Figure 2).

Figure 1: An image of a colour checker car, normally used for color calibration, in the hyperspectral imaging system. This shows the raw image extracted from the camera.

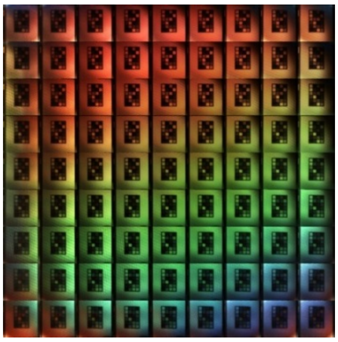

Figure 2: A multicolour image reconstructed from the raw data of Figure 1. The non-uniformity in the individual images is due to experimental artifact.

In conclusion we designed, built and tested a snapshot hyperspectral imaging system using a commercial light-field camera. The camera is polyvalent and can be adapted to many needs. The next step is to replace the Lytro camera with a CSEM module which can allow real-time spectral image extraction.

[1] http://www2.imec.be/content/user/File/Brochures/cmos imagers brochure-april26.pdf

[2] M. Levoy, et al., "Light field microscopy", ACM TOG Transactions on Graphics 25 (2006) 924.

[3] R. Horstmeyer, et al., "Flexible multimodal camera using a light field architecture", ICCP IEEE Int. Conf. on Comp. Phot. (2009) 1.

[4] Lytro, Inc., USA

[5] https://ch.mathworks.com/matlabcentral/fileexchange/49683-light-field-toolbox-v0-4