Characterization and application of a novel high-speed snapshot hyperspectral imaging sensor

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Recently, IMEC Belgium introduced a novel snapshot hyperspectral imaging mosaic sensor with 16 on-chip spectral filters in a matrix of 4x4 filters per pixel. This sensor has been packaged inside a standard camera module by ADIMEC, The Netherlands, to enable fast image acquisition. We present our results of laboratory testing and characterization concerning intrinsic spectral sensitivity, cross-talk and noise of the camera module. We compare our test results with standard push-broom spectral imaging solutions. Last, we use our laboratory demo setup to evaluate the novel hyper-spectral imaging sensor for industrial and medical applications, which typically demand high-speed image processing.

Introduction

Hyper-spectral imaging is a method of great interest in variety of applications ranging from remote sensing, food inspection and sorting to medical imaging, [1]-[2]. The main technological obstacle for low-cost, high-speed data acquisition has been connected to implementation of this system so far requiring complicated optical systems and moving objects to collect hyper-spectral data. Recent developments in the domain of microelectronics enabled emergence of snapshot imaging sensors that can collect hyper-spectral data during single detector integration period [3]. We present our experiments with a novel sensor developed by IMEC and packaged in the standard camera module of ADIMEC. This sensor is a standard CMOS imaging sensor which has monolithically integrated spectral filters on top of each pixel in the mosaic arrangement (extension of Bayer pattern) where 16 spectral bands are sensed on 4x4 pixel matrix, see [4],[5] and [6] for details. Owing to standard packaging, raw image acquisition is done using standard software and off-the-shelf optics.

Spectral characterization of mosaic sensor

We developed a laboratory setup to perform spectral characterization of the Mosaic hyperspectral sensor regarding intrinsic spectral sensitivity and inter-channel cross-talk. We use custom-made monochromator attached to Halogen light-source which we characterized using a calibrated spectrometer directly behind the exit aperture of the monochromator. To record reflectance images on the camera sensor in 16 bands, we use as a target reference standard (Spectralon® SRT-50-050) illuminated by the monochromator output. A set of images is recorded while wavelength is scanned and in this way we were able to calibrate the relative spectral sensitivity of the 16 channels, see Figure 1. In our experiments, camera is equipped with a standard objective to record the images and hence this characterization is done on the camera-lens combination. We performed experiments with several off-the-shelf objectives and the results were the same in all cases, indicating that standard optics does not impose additional spectral influence. In Figure 1, we observe the highest sensitivity for the blue and green bands, and a decreasing sensitivity towards the red spectral region. We also observe partial overlap between different channels. First, some major bands are close to each other, and second, multiple bands exist per channel and create cross-talk between the channels, see Figure 2. In practical applications requiring spectral reconstruction, the observed spectral cross-talk is a particularly important undesired feature that needs to be dealt with using re-mapping of spectral bands. A linear (Figure 3, middle) or non-linear (Figure 3, right) transformation of a recorded hyperspectral datacube (Figure 3, left) can be applied to reduce spectral cross-talk and to map recorded signals to reconstruct the spectral reflectance properties of objects in the scene. This transformation is needed to prepare (hyperspectral) image data for use in classification of objects.

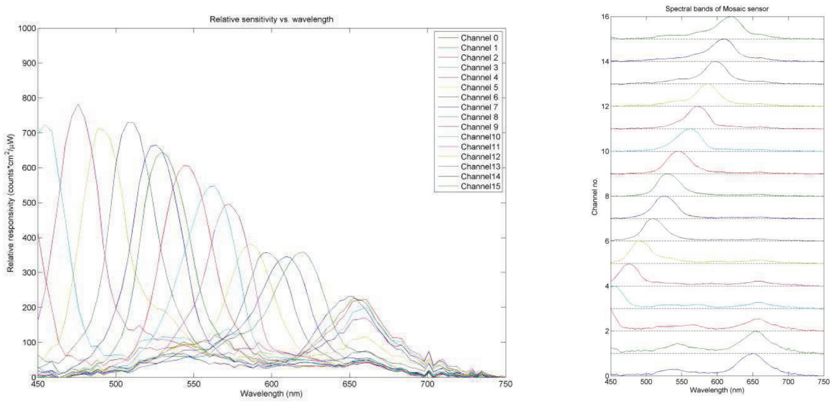

Figure 1 Spectral channel characterization: relative spectral sensitivity (left) and normalized intensity per channel on the sensor.

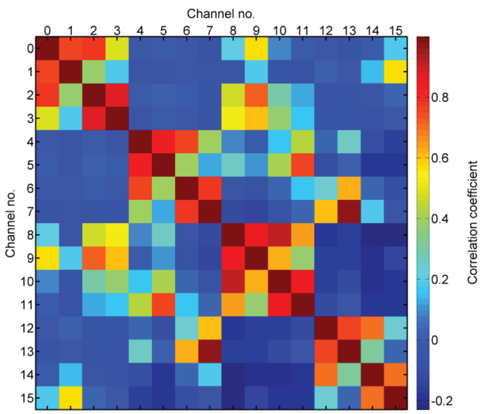

Figure 2 Cross-talk scheme on mosaic sensor represented via correlation coefficients between channels

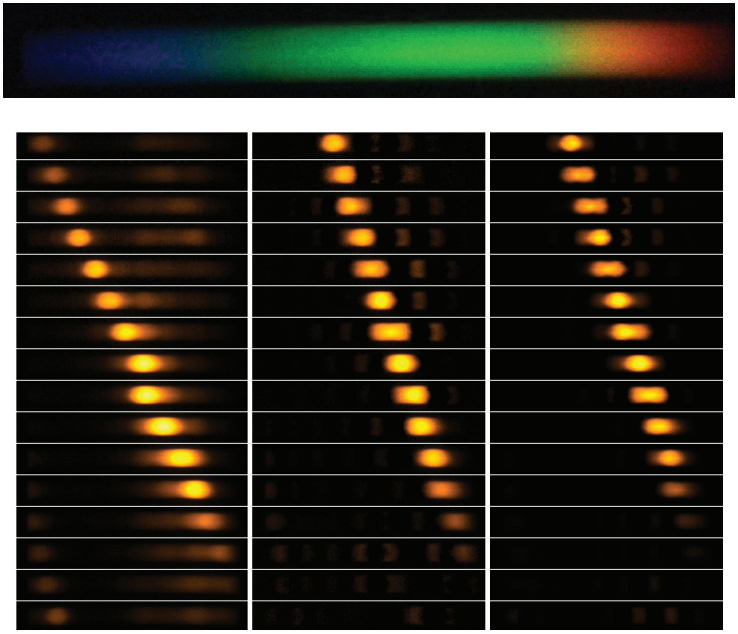

Figure 3 Rainbow pattern recorded with standard RGB camera (top). Hyperspectral datacube recorded on mosaic sensor (bottom): original data (left), data after linear transformation (middle) and data after non-linear transformation (right)

Application example

In the field of hyperspectral imaging, the majority of systems used are scanning devices requiring long acquisition time, complex data pre-processing and non-standard interfaces. Utilization of snapshot imaging system enables tackling typical practical problems with the low acquisition speed, motion blur and/or spectral change during acquisition. Example application area is the inspection and sorting of objects (e.g. food processing or industrial manufacturing) where high speed is of paramount importance. We show an example of spectral response between real and fake (plastic) apple in Figure 4. In these samples, see Figure 4 (left), the colour response is nearly identical in the visible range and thus prevents discrimination between them for both the standard colour cameras alongside with human visual system. However, spectral response measured by 16 channel device (after applying spectral band transformation) show difference between samples.

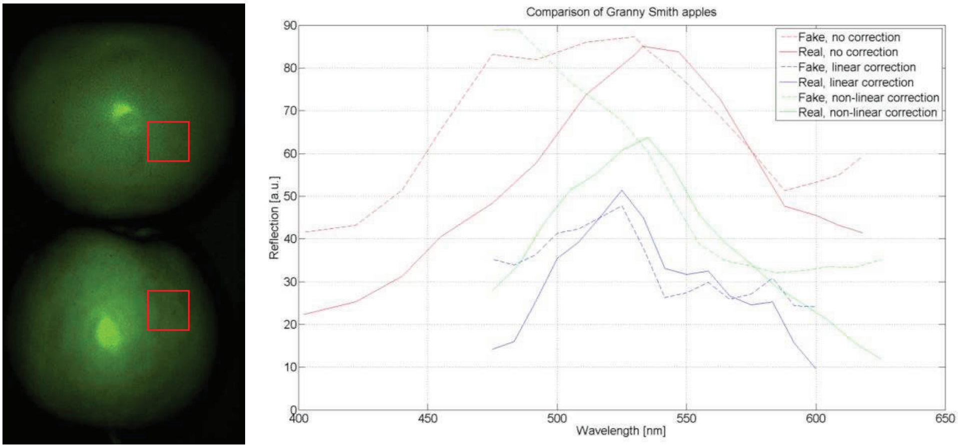

Figure 4 Spectral comparison measurement between fake (left: top) and real apple (left:bottom) represented by relative specteral response in part of the image (right).

Concluding remarks

We performed spectral characterization of novel snapshot images using a setup in our lab and developed algorithms for data pre-processing to deal with intrinsic spectral cross-talk. Results of our study show that spectral characterization of this device is an important step in data pre-processing, and means to tackle spectral cross-talk are precondition for good performance of classification algorithms. Also, we performed first experiments on selected samples aiming at spectral classification of objects.

References

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