Multispectral imaging at longwave-infrared wavelengths by a multi-aperture array of low-cost sensors

Miguel A. Preciado, Guillem Carles, and Andrew Harvey
School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, UK

***Abstract*— A low-cost long-wave infrared (LWIR) multispectral imaging system based on a multi-aperture uncooled LWIR camera array is presented and applied in the detection and classification of substances.**

I. INTRODUCTION (*HEADING 1*)

Snapshot techniques collect multispectral images data cube in a single integration time, and offers some advantages such avoidance of scanning artifacts, robustness, lack of moving parts, and optical throughput [1]. Moreover, the price of uncooled LWIR thermal detectors decreases yearly according to the Moore's Law. A snapshot system based on uncooled LWIR cameras called gas cloud imager (GCI) was proposed in [2] for gas hydrocarbon detection. However, it requires relatively complex optical setup, composed by two lenses, a mapping mirror and a prism array. Here we propose a very simple system which is just composed by an array of cameras with their corresponding objective lenses and optical filters for LWIR (similar to that [3] proposed for visible), where each camera capture one channel image. The reduction of the complexity of the system comes with an increase in the processing complexity, since the camera images need to be co-registered to compensate the effect of the different offset of each cameras. This multispectral imaging scheme offers enhanced dynamic range and sensitivity and relative insensitivity to chromatic aberrations, as well a high degree of flexibility for the selection of the channels, by simply changing the set of optical filters. As examples of applications, we present results of multispectral imaging of various substances for their detection and classification.

The proposed system (showed in Fig. 1) take advantage of the recent availability of very low cost thermal imaging sensors that enables the development of 6 arrayed LWIR cameras under a reasonable budget. The additional elements required for the control of the cameras are also selected to keep the total system cost low.

Every detector capture an image for the corresponding channel by using an optical filter. Besides the cost-effectiveness of the approach, there are some interesting properties of the proposed multi-aperture approach. The operation in a particular channel reduces the sensitivity of each camera to chromatic aberration, allowing the relaxation of the chromatic requirements of the lens, and the reduction of the associated cost. The system also offers a very high degree of flexibility regarding the channels selection, which can be modified by simply changing the set of filters optimized for a particular application.

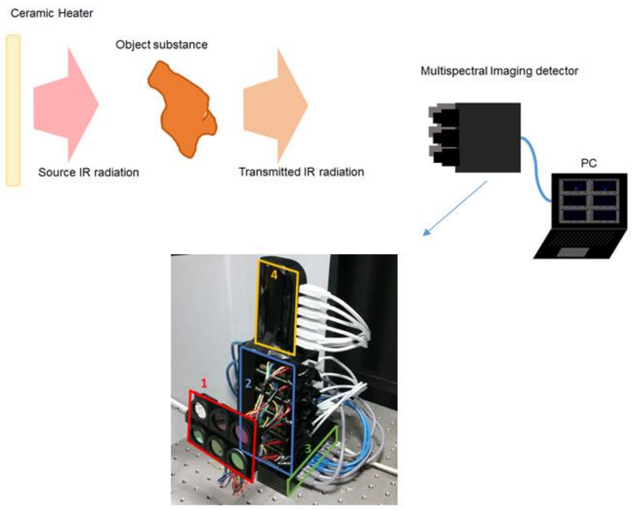

Figure 1. Schematic of the system for substance detection and classification. (1) FLIR LEPTON® based 6x LWIR detectors and filters (2) 6x Raspberry-pi ® based CPU rack. (3) Ethernet switch-hub for networking and (4) USB hub for power supply.

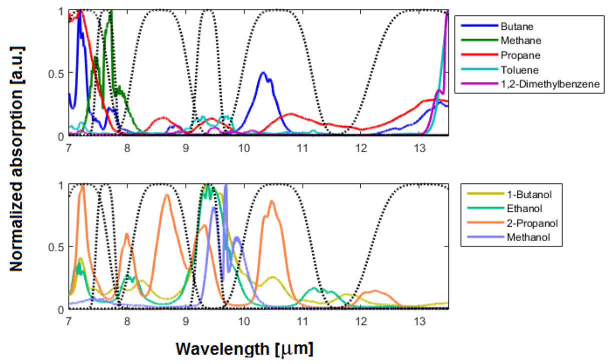

Figure 2. Spectral absorption of gases considered for the gas detection examples. The represented absorption is obtained by smoothing the spectral lines of the gas with a low-pass filter, and normalized by the maximum absorption in the LWIR band.

The simplicity of this multispectral scheme comes with the increase of the complexity in the images processing to compensate different relative offsets introduced in the images captures by the detectors. A calibration using images registration algorithms [4] can be applied in this regard for a real time compensation of this effect, which can operate in real-time as the images are captured.

We have considered the gases absorption profiles represented in Fig. 2, where selection of the filter bands process has been performed aiming to optimize the system sensitivity to the absorption of the object substances obtained from HITRAN (https://www.cfa.harvard.edu/hitran/) and NIST(nist.gov) database, taking also into account the commercial availability of filters.

A calibration of the cameras, represented in Fig. 3, is required in order to register the multispectral data cube, where some reference points are identified across the set of cameras, and use to fit a model that compensate the different cameras orientation and position, as well as the distortion. Figure 4 show some multispectral results from the composition of this data cube for different substances.

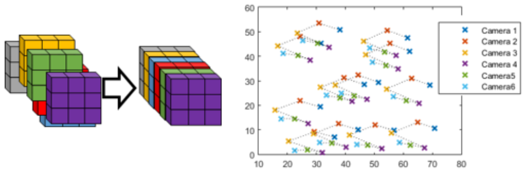

Figure 3. Registration of images by fitting a transformation matrix (magnification, rotation and shift) plus distortion, using target points. (a) Schematic illustration of the registration process of the channels. (b) Example of target points for each camera.

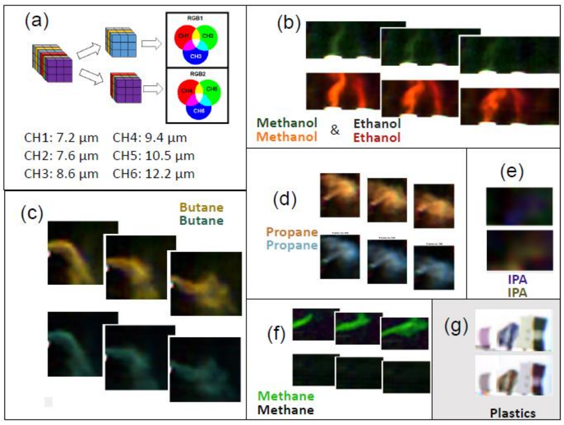

Figure 4. Multispectral results. (a) Schematic explanation of RGB image pairs representing 6 channel multispectral image; (b) to (f) representation of absorption of gases labeled in the figure; (g) representation of transmission for plastics, from left to right PP, PVC, HDPE, LDPE.

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REFERENCES

[1] G. Eason, B. Noble, and I.N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955. (*references*)

[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

[3] I.S. Jacobs and C.P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.

[4] K. Elissa, "Title of paper if known," unpublished.

[5] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.