University of Glasgow | School of Physics & Astronomy

8TH ANNUAL SU2P SYMPOSIUM

05/04/2017

New techniques in computational thermal imaging.

L.V.Cowan, M.A.Preciado, G.Carles, A.R.Harvey

Imaging Concepts Group, School of Physics & Astronomy, Kelvin Building, University of Glasgow, Glasgow G12 8QQ, UK

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Computational Imaging

Through transferring the burden of complexity from precision optics to digital signal processing, where, thanks to Moore's law, high performance can be achieved at very low cost, computational imaging offers lower cost and disruptive new capabilities that are attractive to users and researchers alike. These emerging technologies provide cheaper and more targeted imaging alternatives.

Wavefront Coding

Wavefront coding combines optical coding with computational decoding to yield an order of magnitude improvement in sensitivity to optical aberrations [1], but with the quid pro quo of reduced signal-to-noise ratio[2]. We have demonstrated that a pipelined imaging-averaging technique can enable recovery of images that retain high signal-to-noise ratio as shown by the graph below.

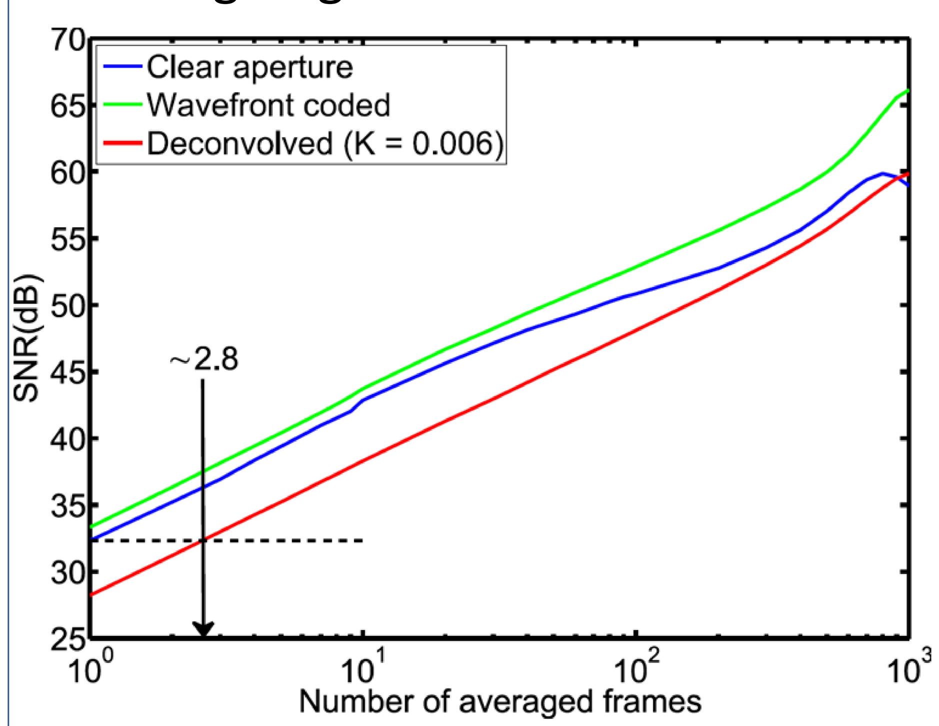

Figure 1 Improvement in SNR against number of averaged frames obtained from micrographs of a distortion target imaged in transmission at 540 +/- 20nm.

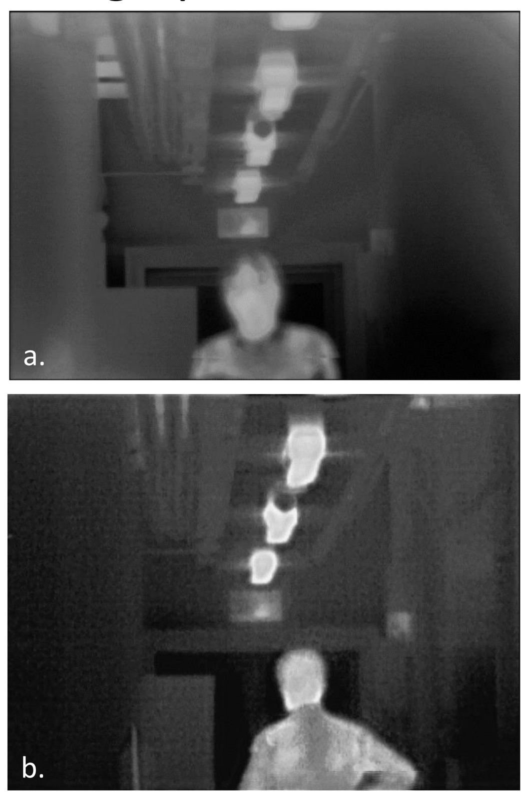

Figure 2 (a) Thermal image of corridor (b) Wavefront coded image of corridor.

Multispectral multi aperture imaging

Multi-aperture imaging employs arrays of subsystems to achieve higher performance from simpler optics using integrated computational image recovery from individual sub-images [3] . Using multi-spectral, multi-aperture imaging we have imaged gas clouds in the thermal infrared, as well as plastics, for their detection and classification. Each multi aperture camera captures a specific channel within the course LWIR band, equivalent to that successfully demonstrated in the visible band in [5].

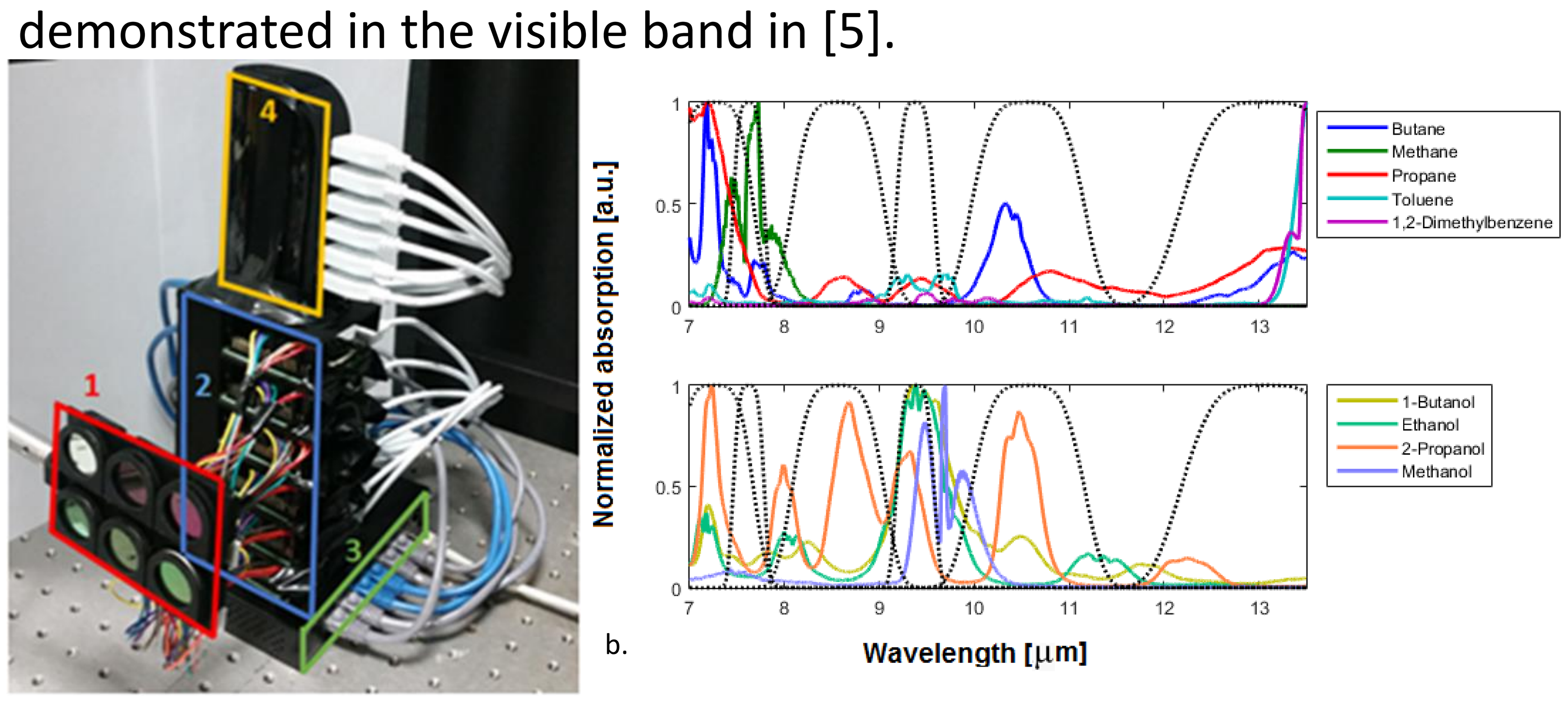

Figure 3 *Low-cost multispectral system in LWIR (a). Array of detectors (FLIR Lepton LWIR camera) (1), controlled by a rack of CPUs (raspberry pi), all connected by Ethernet (3), and powered by USB (4). (b)* Spectral absorption of the target gases used in the selection of the filters set. The represented 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.

Multi aperture super resolution imaging

A super-resolution (SR) system in the long-wave infrared (LWIR) can be achieved when based on a synchronous array of low-cost uncooled LWIR cameras. This system allows us to image with enhanced angular resolution and implement 3D integral imaging capabilities imaging through obstacles at full-frame video rate. Additionally we use variations of the multi-aperture architecture, foveal imaging [4], targeted super resolution, an enhanced depth-of-field variation on multi-aperture imaging which allows for non-linear mapping of light rays to the sensor plane using prisms to direct the light.

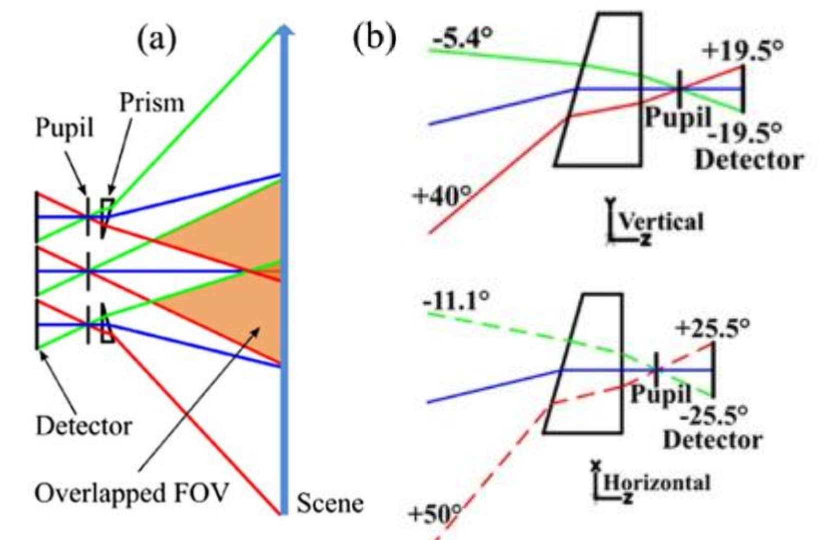

Figure 4 (a) Principle of multi-aperture foveated imaging approach (b) Right-graphs illustrate the modification of the FOV.

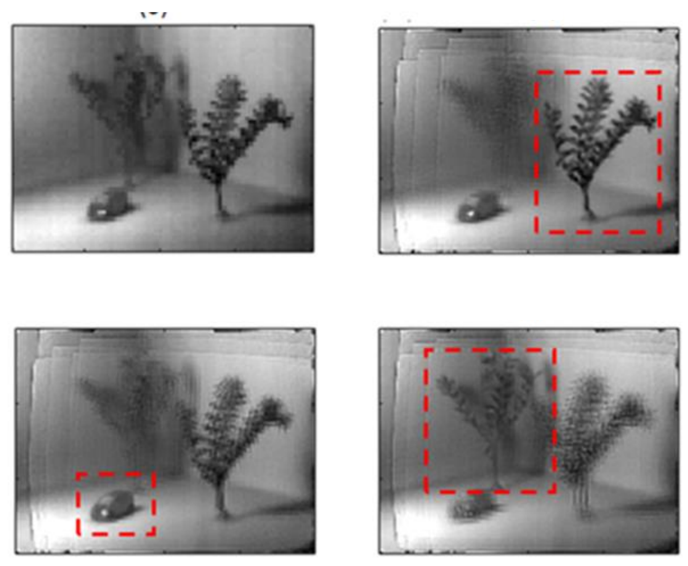

Figure 5 The results of 3D volumetric reconstruction of scene by simultaneous integral-imaging super-resolution.

Time resolved super resolution imaging

When an imager is handheld there is randomized motion between the imager and the scene, requiring frame-to-frame co-registration. In addition, this movement will tend to randomize the sampling phase of the scene by the detector array thus enabling a high-quality super-resolution image to be computed from the video frame sequence [7-9]. The redundancy present in the wavefront coding pipelined fusing algorithm provides a platform to combine this technique with time-sequential super resolution.

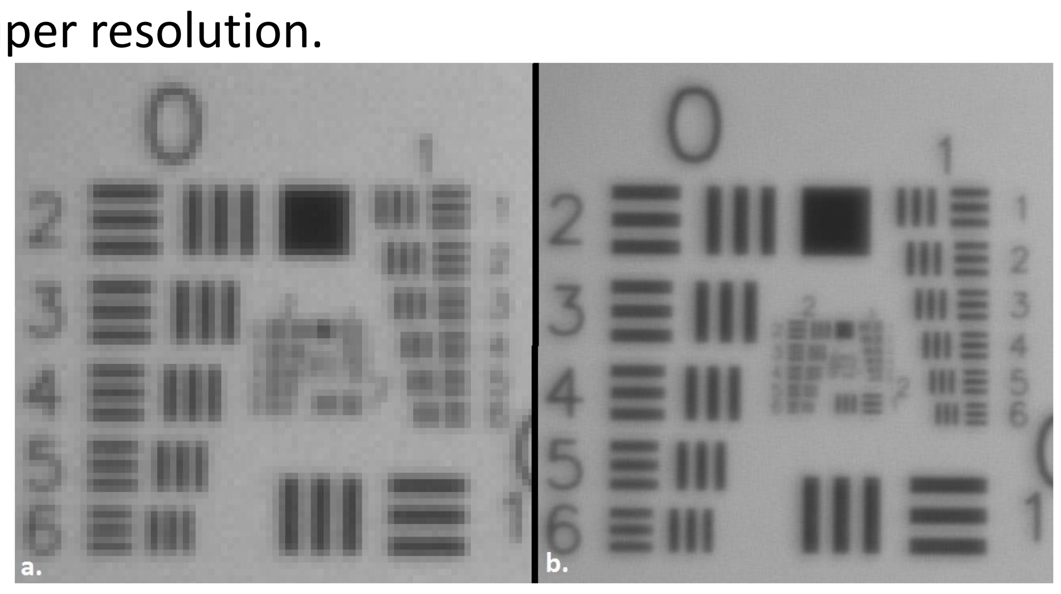

Figure 6 (a) a resolution-limited video frame of a USAF target taken with a visible handheld camera; (b) a frame from the same footage time-sequentially super-resolved.

References

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