Live Demonstration: Depth from Focus on a Focal Plane Processor Using a Focus Tunable Liquid Lens

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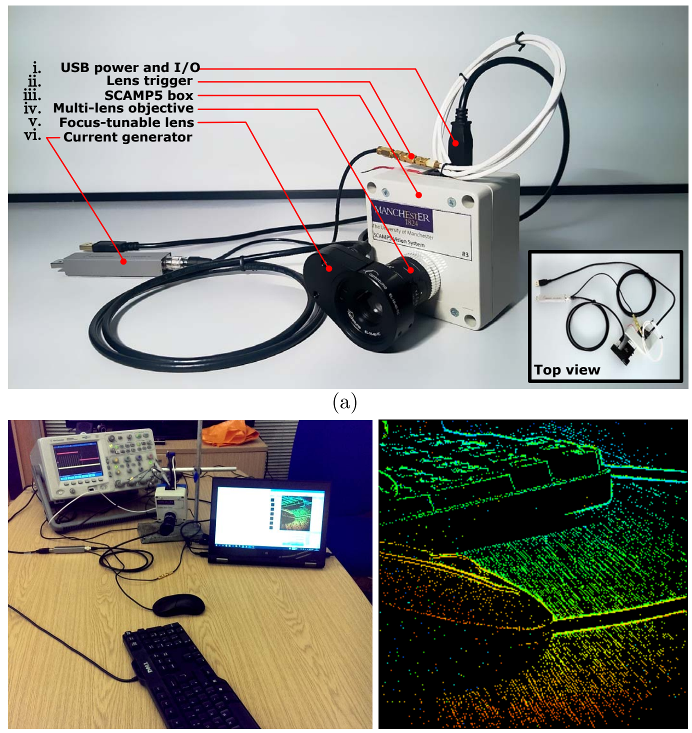
***Abstract*—We demonstrate a 3D imaging system that produces sparse depth maps. It consists in a liquid focus-tunable lens whose focal power can be changed at high speed, placed in front of a SCAMP5 vision-chip embedding processing capabilities in each pixel. The focus-tunable lens performs focal sweeps with shallow depth of fields. These are sampled by the vision chip taking multiple images at different focus and analyzed on-chip to produce a single depth frame. The combination of the focus tunable-lens with the vision-chip, enabling near-focal plane processing, allows us to present a compact passive system that is static, monocular, real-time (> 25FPS) and low-power (< 1.6W).**

I. Introduction

A simple way to reconstruct depth from a single, static, passive camera is to sweep its focus in a scene using a lens featuring a shallow depth of field such that points at a particular distance of the camera (i.e depth) only fall in focus for a particular focal power of the lens. By taking multiple images at different time during this focal sweep and analyzing which points in these images are in focus, it is thus possible to relate those to their distance from the camera [1]. We use this principle to build a depth imaging system using a focus-tunable lens. By not using any mechanical part it allows us to sweep focus at high-speed. It is placed in front of a vision chip equipped with a cellular processor array in which each pixel of the sensor is collocated with memory and a processor. Our system profits from the massively parallel computation this sensor-processor offers to perform the analysis of focus on a frame as another is being acquired. It is thus possible to analyze on-chip many images to produce a single depth image with as many depth levels as intermediate images without the need to output any of these intermediate samples to a third-part, potentially power-hungry processing system; such a system running at 25FPS (depth frames) with a resolution of 256×256 pixels using 32 depth levels computed from 8b frames, would require the transmission of 800FPS (intermediate frames) and the processing of 52MB.s^{-1}.

II. Demonstration

This demonstration, pictured in Figure 1, consists in a liquid focus-tunable lens [2] (Fig. 1a-v) mounted on top of a multi-lens objective (Fig. 1a-iv) equipping a vision chip [3] (Fig. 1a-iii). The tunable lens operates with triangular sweeps driven by a precise current generator (Fig. 1a-vi) whose frequency can range up to 1kHz with 0.25Hz increments. In the simple case when one wants to produce a depth frame per sweep of the lens, three parameters configure the system [1]: First, the frequency at which the lens operates determines the frame-rate of the system (the system starts sampling after a trigger (Fig. 1a-ii) coming from the current-generator), secondly the number of depth levels determine how many times the system samples focus by taking images, finally a delay parameter controls the exposure of each image sample and ensures the uniform distribution of the levels across a sweep. These parameters can be changed online, by default the system operates at 25FPS with 16 to 32 levels in normal lighting conditions but can be tuned to produce more levels (up to 256) with lower frame rate or operate at a higher frame rate with fewer levels (given enough light). The system outputs depth frames via USB (Fig. 1a-i) as shown in Figure 1c.



(a)

(b) (c)

Fig. 1. (a) and (b) show photographs of the SCAMP5 system with the lenses and a setup imaging a scene (c) shows the resulting depth image.

References

[1] J. N. P. Martel *et al.*, “High-speed depth from focus on a programmable vision chip using a focus tunable lens,” submitted to Proc. of the IEEE Internat. Symp. on Circuits and Systems, ISCAS’17.
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