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TPM: A Novel Sensor for Very-High Speed Imaging with Variable Frame Depth

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Developed by the Science and Technology Facilities Council (STFC) and Cordin Scientific Imaging, presented in this paper will be the Time Pixel Multiplexing (TPM) sensor, a high-speed camera with variable frame depth. Based around the principle first published by Gil Bub [1], TPM is a 1024x1024 CMOS image sensor with the ability to image at speeds up to 10Mfps by changing which pixels are active through time.
In a conventional CMOS image sensor, the array of pixels can either be active all at the same time with global shutter, or in a row-by-row basis as in rolling shutter, but in both the final end goal is to create one coherent snapshot of a moment in time. This means that to achieve high-speed imaging in one device a combination of fast pixel-level readout with exponentially faster full sensor readout [2] or by increasing the pixel size through in-pixel memory with a slow readout [3].
However, by carefully controlling when each pixel is active a subset across the full array can be integrating at the same time whilst another is reading out and a third set are held in reset before integration, as shown in a rough timing diagram in Figure 1. In this way it possible to capture one single image that can then be processed into a sequence of variable frame depth where the only trade-off is the final resolution. Shown below in Figure 2 is one such image where a 4x4 TPM mode has been used to produce a 16-frame video at 256x256 pixel resolution. The TPM mode can be varied between the two extremes as the user desires, from a single 1 Mpixel frame up to over 1 million sequential frames at a single pixel resolution, all at speeds of up to 10Mfps.
This paper expands on initial results published in 2021 [4], and aims to give an overview of the technology, the challenges and developments required within, as well as present results from the first commercially available camera using the STFC-developed TPM sensor from Cordin Scientific Imaging.

Figures:

Figure 1: Simplified readout control graph showing a set of four pixels being held in reset, integrating, being sampled, and then read into the column as each line set is activated.

Figure 2: An example 4x4 video of a bridged wire test: a) The complete 1024x1024 frame; b) separated into 16 frames, with time increasing from top left to bottom right vertically; and c) a single 256x256 image

References:
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