The ToF CMOS Visual Cortex Project

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Introduction

Thermal neutron detection techniques are split in “imaging” techniques and “counting” techniques. For the specific application of Time of Flight (ToF), however, the only option as of today is “counting” because no camera is fast enough to have the sustained time resolution of the order of a few micro seconds. CMOS camera's sensitive elements have the potential of reaching such time resolution, but in today's cameras this is not yet exploited. We propose to take up the challenges that go with the design of a CMOS-like camera that can sustain a continuous frame rate of the order of 100 000 fps.

The Concept

The individual pixels of a CMOS sensor are capable of a time resolution in the 10 micro second range, as such, the potential of a 100 000 fps rate camera exists. The challenges are on the level of the signal readout and S/N level, the digitization, the data flux and the processing.

The idea is to imitate the human visual cortex, that is, to treat the image information on-line, and only retain useful extracted information, instead of storing the raw image information.

Challenges

Front-End

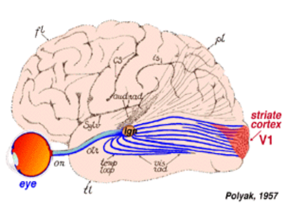
- Flash ADC, ~200 MHz sampling
- Faster multiplexing vs S/N ratio (pixel filter ?)
- ADC probably *too hot*, must be off-sensor
- Challenge: get 2000 analogue signals off-chip

Data Flow

- 2000 ADC at 200 MHz at 16 bit = 800 GB/s of raw image data!
- Impossible (and unreasonable) to store
- Difficult to transport

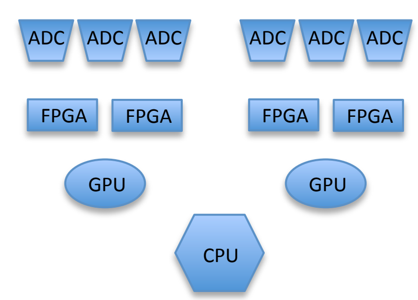
Processing

- 400 000 000 000 pixels to be treated per second
- Centralized processing impossible
- Advanced distributed image feature recognition needed



Visual cortex philosophy

- Layered data reduction
- Exploiting close-range correlations
- From pixels to abstractions
- The output of the camera is not an image, but information!
- As human, we don't see pixels, but objects



Layered processing

- Nearby ADC to FPGA for first level fast signal treatment, mainly hot pixels reduction and threshold discrimination
- FPGA to several GPUs for more complex image manipulation/correction e.g. pattern recognition, calibration, further specific noise reduction
- CPU at the end for final data composition and handling of the data stream to external acquisition

Potential Impact

- The advantages of a camera capable to sustain a 100 000 fps continuous rate with integrated intelligent image treatment and reduced output data flow for thermal neutron ToF applications are evident. This is especially true when considering the new pulsed sources where the instantaneous flux is by far higher that what a classical neutron detector can treat within a reasonable dead-time.
- On the medical side, fast kinetic phenomena like drug absorption at the cellular level have timescale in the tens of μs region.
- The camera could be of potential interest for industry too when looking at the onset of material stresses, deformations or ruptures, all events for which stroboscopic techniques can not be applied.