High Speed Edge Detection Using a Retinal Ganglion Cell-Based Filter on a SPAD Array.

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Retinal Ganglion Cells (RGCs) are the last layer of neurons in the retina's neuronal layers, which pre-process the visual signal and work to extract specific features like colour, motion, and textures. Each RGC receives spike-information input from photo-receptor cells that detect photons within their receptive field, which can be split up into central and surrounding receptive fields (CSRF). Different RGC types excite upon receiving spikes from certain combinations of CSRFs, as shown in Figure 1 [1]. A critical process that RGCs undertake is extracting low-level features of a scene and sending those to the brain, allowing it to react as quickly as possible. A moving object causes a large excitation in RGCs positioned at the edges of the projected image of the object, as this is where the light intensity changes between the CSRFs and so high spatial contrast occurs. When inferring the identity of an object in fight or flight situations, its outline is advantageous and so quick edge detection is important [2].

In practice, this edge detection works similarly to how a dynamic vision sensor (DVS, otherwise known as event cameras) operates. These cameras measure brightness changes per pixel, and asynchronously send a signal only when the brightness change exceeds a certain threshold. They therefore excel at edge detection for fast moving objects in a high dynamic-range scene, with a high temporal resolution [3]. They falter however with either slow or stationary objects in a scene, due to the lack of sufficient brightness change in the image [4].

We use an asynchronous Single Photon Avalanche Diode (SPAD) array and a pre-processing filter based on RGC CSRFs to capture images of fast moving objects in a scene with high temporal resolution. The asynchronicity of the SPAD replicates both the fast detection of photons by photo-receptor cells as well as the high temporal resolution of the DVS. However since a SPAD detects individual photons and not brightness changes like a DVS, objects are still detected when moving slowly or stationary within the scene, shown in Figure 2. Applying the RGC filter also increases data throughput by reducing the spikes required to generate the image, complimenting the high speed nature of the asynchronous SPAD arrays. We also compare the use of a conventional square SPAD array with a hexagonal layout SPAD array, which closer mimics the photo-receptor cell layout. This paves the way for asynchronous SPAD systems to be used in compact, low power applications such as automotive or autonomous systems where precise, high-speed, dynamic object tracking is critical.

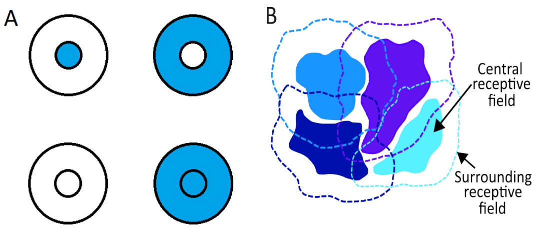

Fig. 1: *A: The 4 different possible combinations of photons being detected (blue) and not detected (white) in the CSRF, B: An example of the realistic layout of multiple RGC's CSRFs.*

Fig. 2: *The edges of shapes generated by the SPAD and RGC filter on the University of Glasgow's Advanced Research Centre (Left), compared to the ground truth image (Right).*

References

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