Real-time FPGA Implemented Image Analysis Algorithm for Target-RGC Selection

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Introduction

Current retinal implants stimulate all of the locally available Retinal Ganglion Cells (RGCs) indiscriminately, only linearly dependent on the respective pixel brightness. To mimic natural vision more closely, it is necessary to process the optical input of the implant in a way the underlying retinal network would do it, to receive cell-type selective activation functions.

Methods

A widely used mathematical representation of RGC behaviour is the Difference of Gaussian (DoG) algorithm. For an ON-RGC, it can be described as

$DoG_{ON} (x,y,t) = I(x,y,t) * \Bigl(\frac{1}{2\pi \sigma^2_{c}} e^{-\frac{x^2-y^2}{2 \sigma^2_{c}}}- \frac{1}{2\pi \sigma^2_{s}} e^{-\frac{x^2-y^2}{2 \sigma^2_{s}}} \Bigl)$,

where $I(x,y,t)$ represents the input frame, dependent on its x and y pixels and its timestep t. The size of the cell-type dependent receptive field (RF) is defined by the parameters σ_c and σ_s. Together with other mathematical operators, this operation is to be realized in FPGA logic with minimum resource requirements.

Results

For an efficient implementation, it is not required to store an entire image frame into internal FPGA memory. Instead, the serial data output of a camera can be used to perform the image analysis sequentially, while only three first-in first-out (FIFO) registers are required to enable the analysis of RF sized structures, reducing the required parallel convonlution units to three. The correlation coefficient between the model output and natural RGC behaviour was 0.969 (ON-transient), 0.915 (ON-sustained), 0.986 (OFF-transient) and 0.83 (OFF-sustained).

Conclusion

The shown implementation of the DoG-algorithm can differentiate between eight different RGC-subtypes extracted out of greyscale images. At a fixed frame rate, the maximum image size is dependent on the FPGA's master clock frequency. If a frequency of 200 MHz is used, the maximum image size is 5 megapixels, making this implementation superior to event cameras, that are also usable for this task. This implementation is thus very suitable for use in future retinal implants, as the algorithm's potential lies way above currently available stimulator resolutions.