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Computer Vision on the SpiNNaker Platform

Why vision?

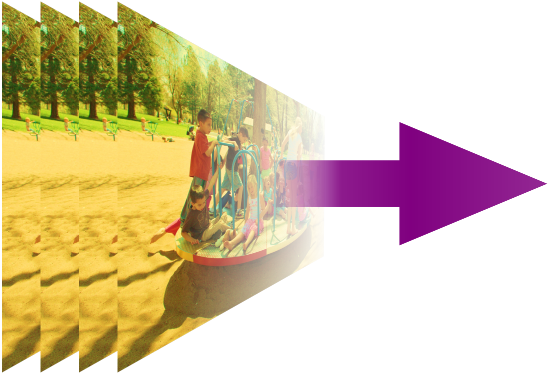
A picture is worth a thousand words

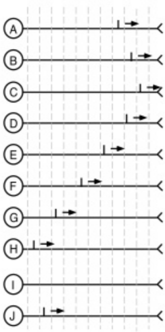
Why SpiNNaker?

- Spiking Neural Network Architecture
- Massively parallel processing
- Network capabilities

SpiNNaker

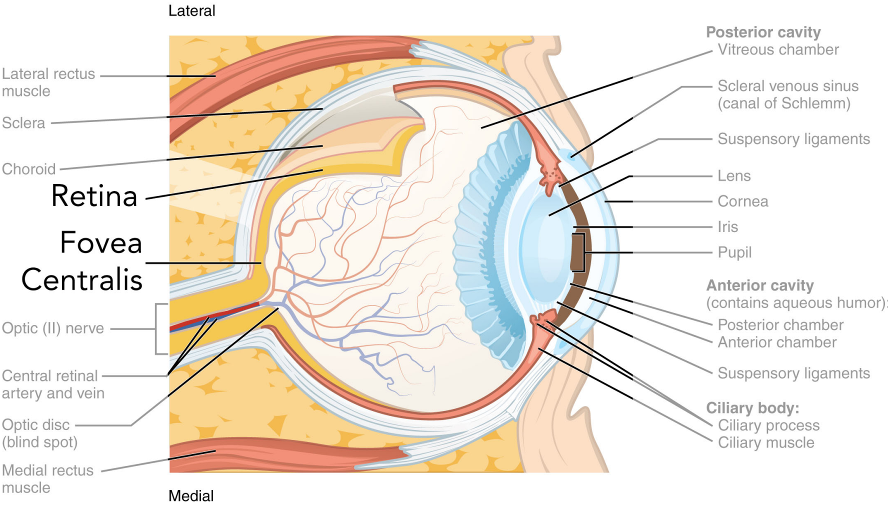
Current work





Convert images/video from a frame-based camera to spike trains

Retina



Lateral
Lateral rectus muscle
Sclera
Choroid
Retina
Fovea Centralis
Optic (II) nerve
Central retinal artery and vein
Optic disc (blind spot)
Medial rectus muscle
Medial
Posterior cavity
Vitreous chamber
Scleral venous sinus (canal of Schlemm)
Suspensory ligaments
Lens
Cornea
Iris
Pupil
Anterior cavity (contains aqueous humor):
Posterior chamber
Anterior chamber
Suspensory ligaments
Ciliary body:
Ciliary process
Ciliary muscle

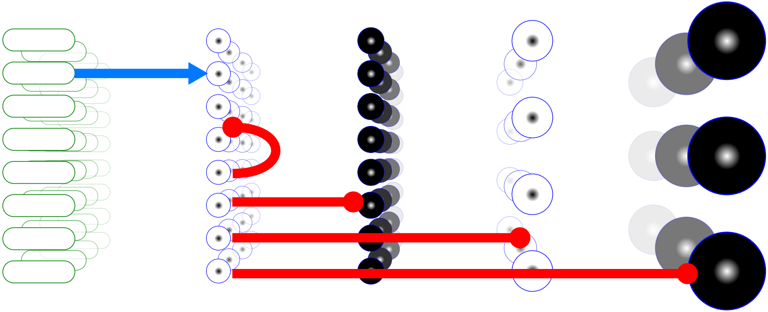
First retinal model

- **Foveal pit** model with *rank-ordered* output [1]
- Center-surround behaviour

Midget Off-centre | Midget On-centre | Parasol Off-centre | Parasol On-centre

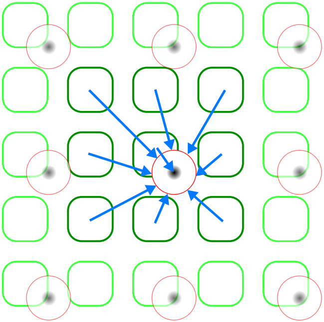
[1] Bhattacharya and Furber, "Biologically Inspired Means for Rank-Order Encoding Images: A Quantitative Analysis"

Foveal pit connections

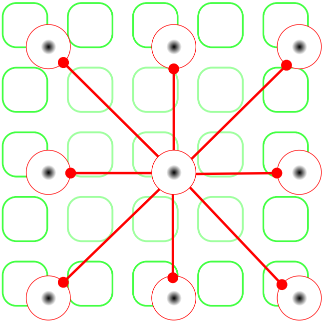


- Excitatory connections from photoreceptors to ganglion cells.
- Inhibitory connections to and from ganglion cells.

FoCal



Excitatory
Convolution
Parallel



Inhibitory
Adjust weights
Serial

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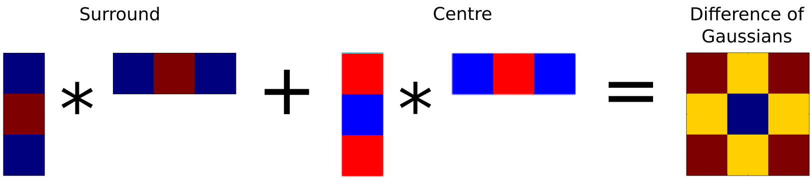
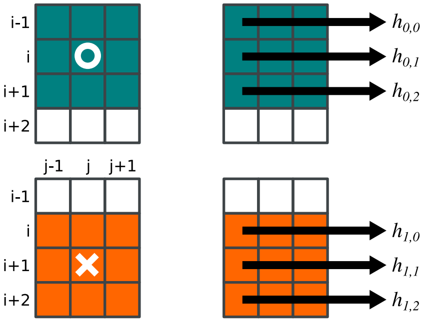
FoCal - convolution



Separated, four 1D convolutions instead of one 2D. Better for parasol cells.

FoCal - convolution

$$h_{i,j} = k_0 \cdot I_{i,j-1} + k_1 \cdot h_{i,j} + k_2 \cdot h_{i,j+1}$$



$$v_o = q_0 \cdot h_{0,0} + q_1 \cdot h_{0,1} + q_2 \cdot h_{0,2}$$

$$v_x = q_0 \cdot h_{1,0} + q_1 \cdot h_{1,1} + q_2 \cdot h_{1,2}$$

$$\Downarrow$$

$h_{1,0} = h_{0,1}$

$h_{1,1} = h_{0,2}$

Shared between pixels **o** and **x**

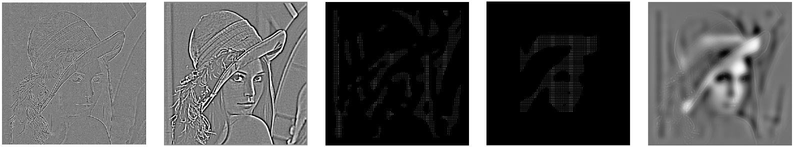
$$\Downarrow$$

$$v_x = q_0 \cdot h_{0,1} + q_1 \cdot h_{0,2} + q_2 \cdot h_{1,2}$$

Tiled, separability based, reuse calculations. Better for midget cells.

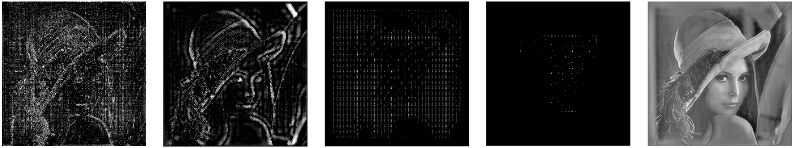
Foveal pit results

- Convolution of 4 cell types using OpenCL @ 12 fps (~60 MOps/sec)
- Issues: Memory transfers for huge kernels



Foveal pit results

- Issues: massive connectivity (~3.4 billion) or serial process
- Neural approach with SpiNNaker



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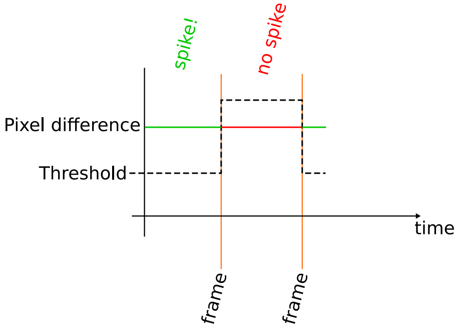
Second retinal model

- Emulate Dynamic Vision Sensor (DVS)
- Sense changes in illumination
- Per-pixel adaptive threshold



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DVS emulator

- Camera bound dynamic range and spatial resolution
- Cheaper and easier to use!

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Summary

- Real-time convolution is possible
- Working on SpiNNaker based FoCal
- Submitted for paper and poster
- DVS emulator, working @ 25 fps on OpenCL ... but needs more testing

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The Future

- Keep improving video sources, custom hardware
- Polychronization
- Learning with time-based spikes
- Spatio-temporal patterns

Polychronization

- Networks with delays
- Spike-timing encoding
- Connectivity similar to FoCal

The End

Thank You!

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