

Information Propagation and Classification in Living Neural Networks

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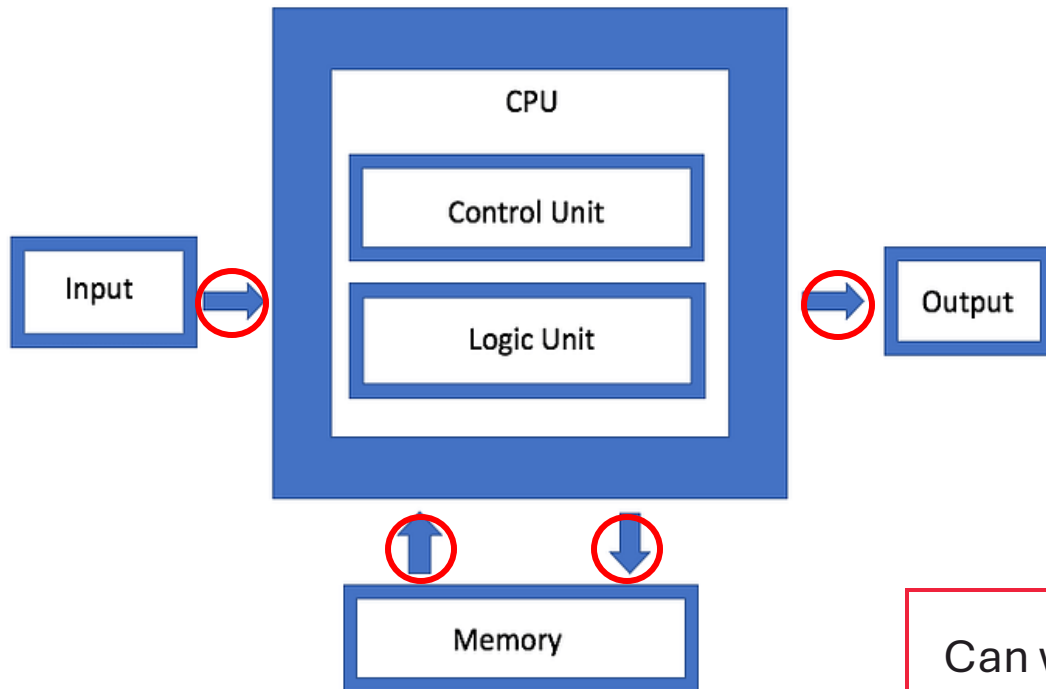
<http://hybrid-ai.umd.edu/>

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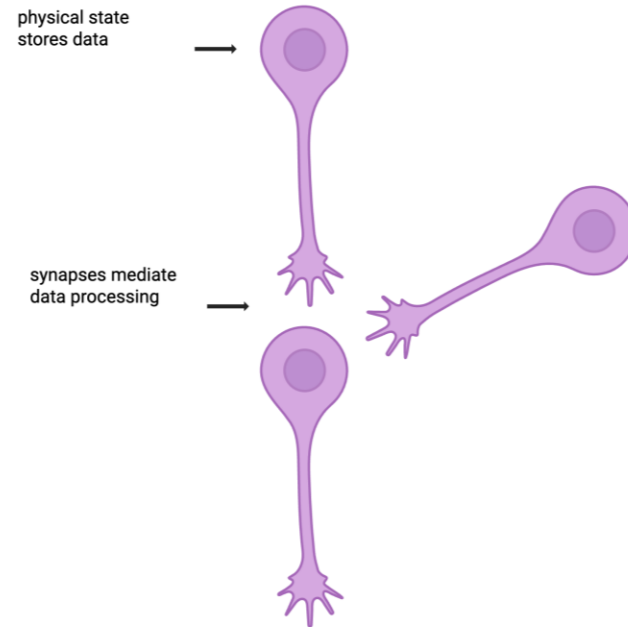


Biocomputing motivation (non Von-Neumann architectures)

- Memory and compute are localized
- Information is binary
- Suited for digital operations
- Compute is mediated by cell network interactions
- Memory is complex
- Information is a dynamical system
- Suited for analog operations



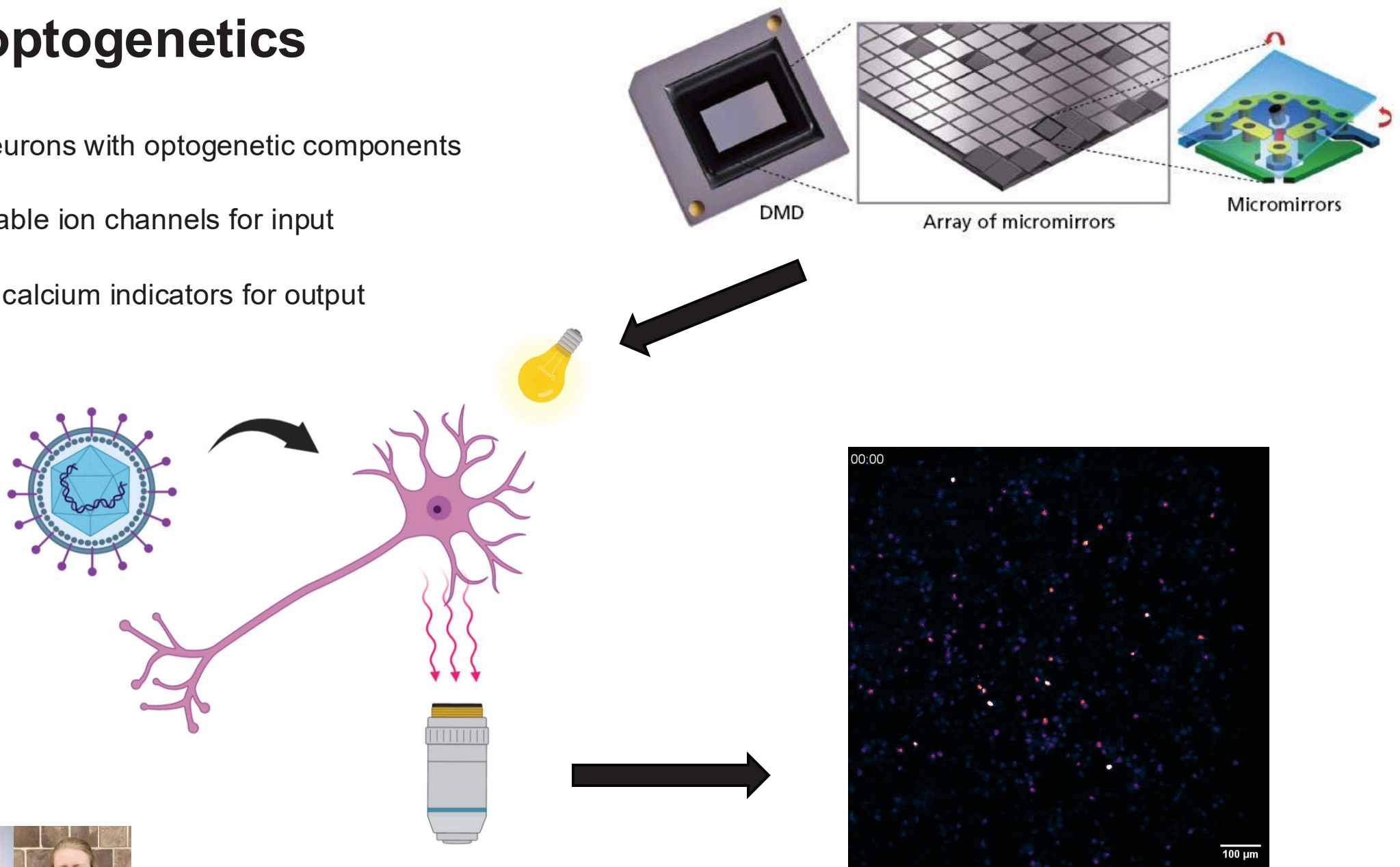
Can we use them together?



Created in <https://BioRender.com>

I/O with optogenetics

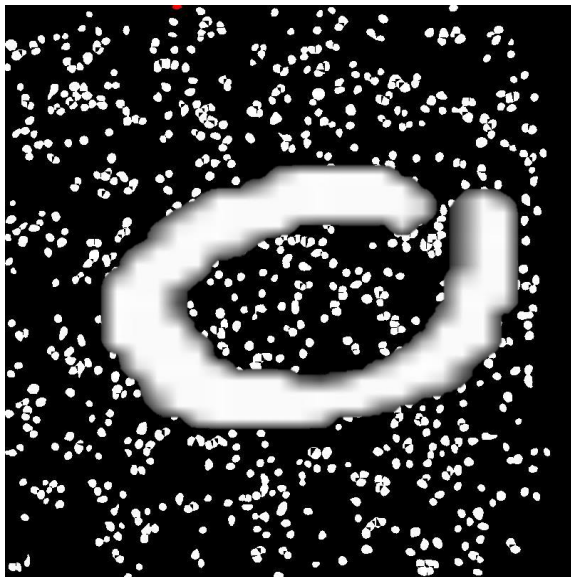
- Transfect neurons with optogenetic components
- Photostimulable ion channels for input
- Fluorescent calcium indicators for output



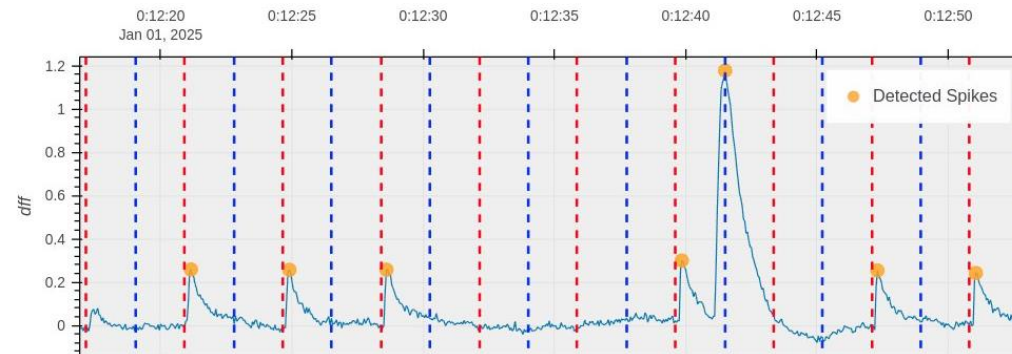
*Work by Kate O'Neill, Johnathan Long, Sylvester Gates, Anna Emenheiser (Losert Lab)

Image classification with neurons

- Stimulate cells with 0 or 1 images and observe calcium responses
- Train simple linear layer with labels to predict an output class (no convolution, no activations)
- Validate without labels



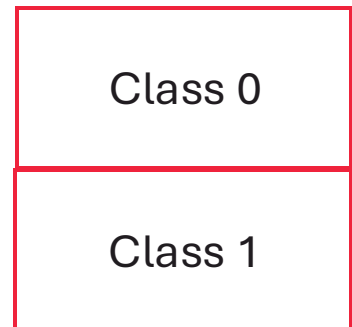
photostimulation



Calcium signals (stimulation times marked by vertical lines)

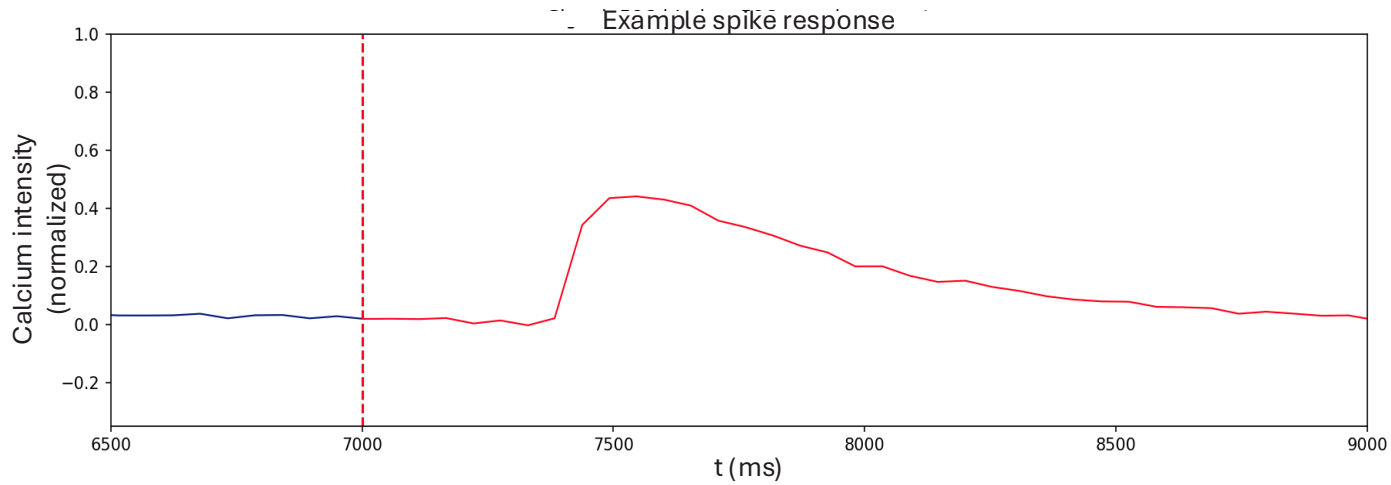
$$\begin{pmatrix} s_1 \\ s_2 \\ \vdots \\ s_n \end{pmatrix}$$

Calcium response vector

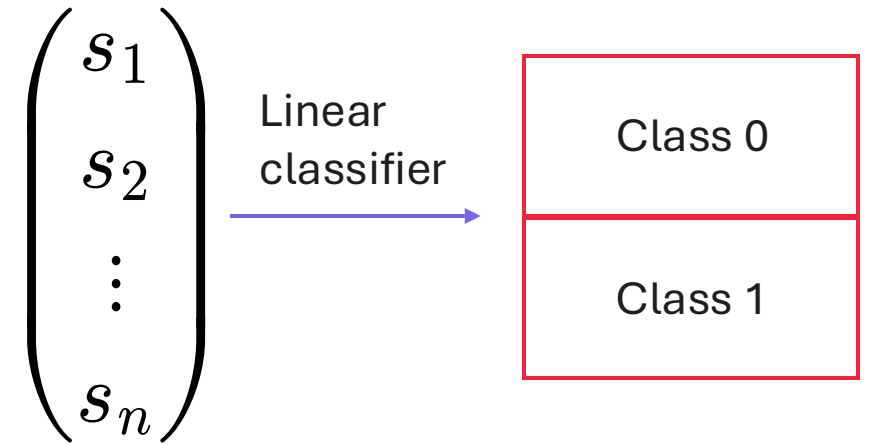


Linear classifier

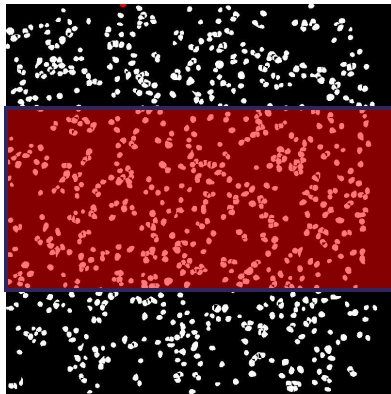
Hybrid classification performance and propagation



Example spike response

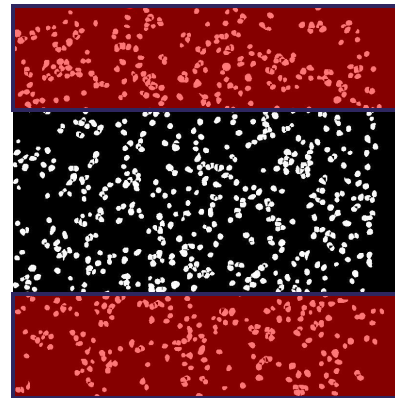


Training on stimulated region

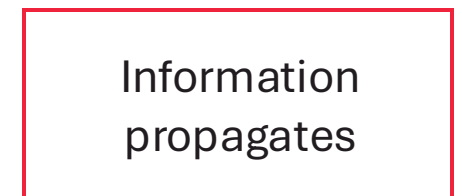


94% accuracy

Training on non-stimulated region

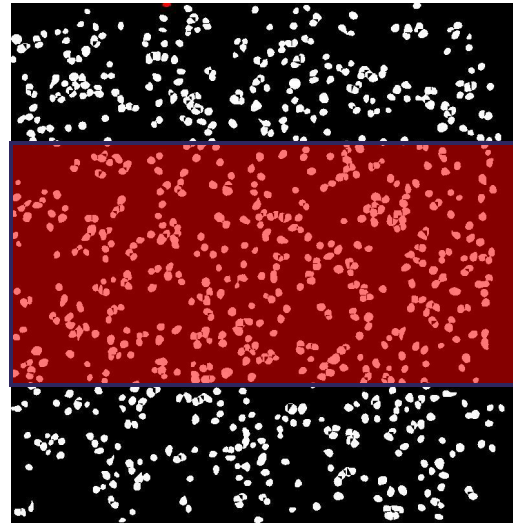


94% accuracy

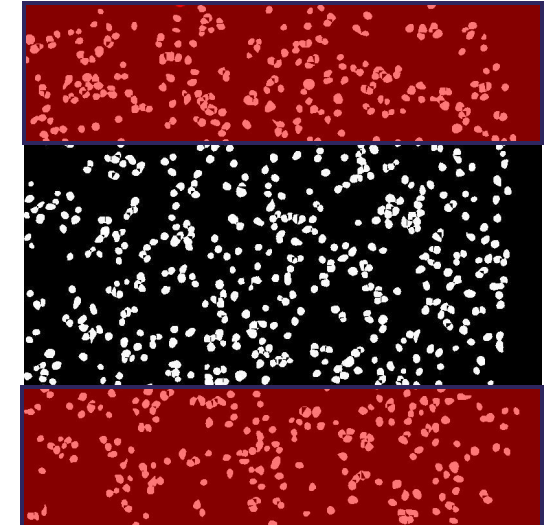


Conclusions

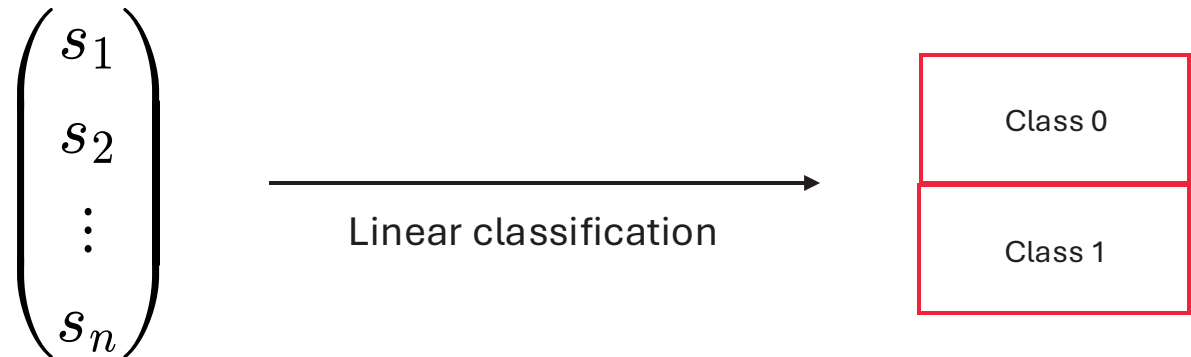
- Sparse spatial information is integrated and propagated with negligible loss
- Cells may transform spatial information into a temporal pattern
- Biology and computers may work together to tackle multistage problems



94% accuracy (stimulated)



94% accuracy (transmitted)



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