Classification model based on images and spiking data from responses of Retinal Ganglion Cells

By: Bani Prasad Swain, Elham Shafiei, Joao Pedro Carvalho Moreira, Paulo Victor Chagas, Nilou Ghazavi, Kosha Srivastava

neuromatch academy

Pod: Waterzooi (Vision group)

Introduction: Biology behind visual processing

- Light enters the front of the eye and reaches the retina.
- Photoreceptors at the back of the retina convert light into signals and sends them to bipolar and retinal ganglion cells (RGCs).
- Axons from retinal ganglion cells form the optic nerve, which carries signals from the eye to regions of the brain that process vision. Those regions include the lateral geniculate nucleus (and other areas), which relays signals to the visual cortex.

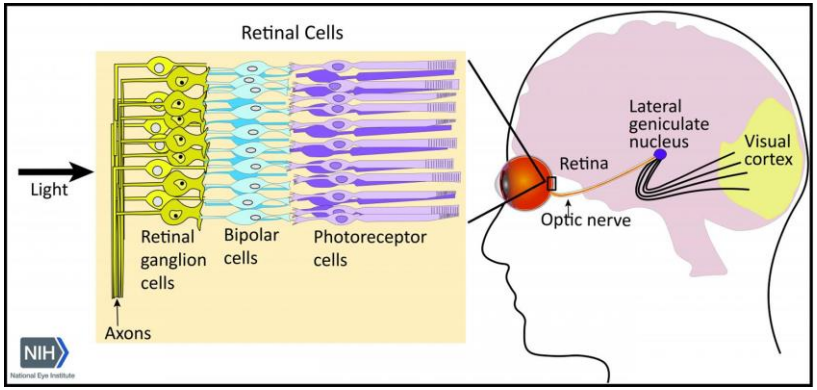


Figure 1. Circuitry of the Retina [1]

Literature Review

- The mechanism behind the decoding of the information received by the RGCs is not completely understood.
- In an attempt to understand this process, researchers have modeled artificial neural networks (ANNs) that try to reconstruct images from spikes data collected with the help of microelectrode arrays placed on the murine retina.
- In one such research, the trained convolutional neural network model accurately reconstructed novel facial images solely from RGC firing data.
- The researchers used the monochromatic version of the Fundacao Educacional Inaciana (FEI) face dataset of 200 individuals with 14 photos per person as visual stimuli.
- Gap in literature: It has not been studied if the spikes data can be correctly labeled to its corresponding image by ANNs.

Figure 3. 14 photos of each individual [3]

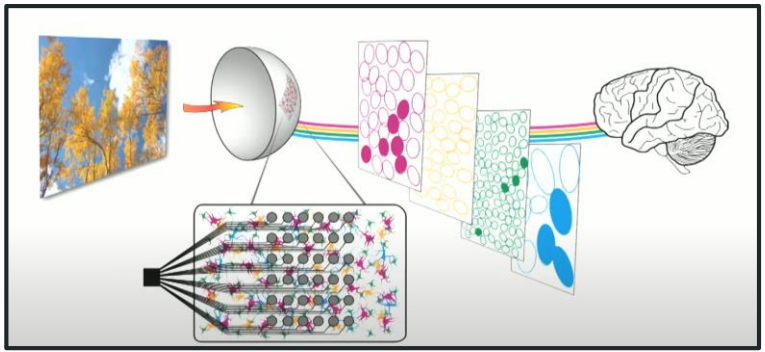


Figure 2. Electrode contactsl [2]

Goal

- We hypothesized that if the neural networks can correctly label the spikes data to the corresponding image, it may give us further insight into how the visual processing system works at the level of the RGCs.
- To investigate this hypothesis, we created a neural network model to classify labels using images as an input and a second model to classify labels with the spiking data as an input.

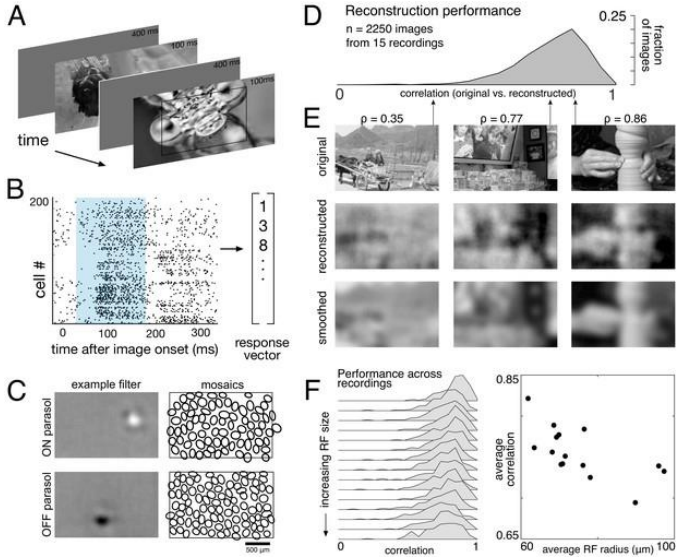


Figure 4. Image Reconstruction from Responses of RGCs [4]

Model

```
classification_net(
  (layer1): Sequential(
    (0): Conv2d(3, 16, kernel_size=(5, 5), stride=(1, 1))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (layer2): Sequential(
    (0): Conv2d(16, 32, kernel_size=(3, 3), stride=(1, 1))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (dropout): Dropout(p=0.2, inplace=False)
  (relu): ReLU()
  (linear1): Linear(in_features=6272, out_features=2000, bias=True)
  (linear2): Linear(in_features=2000, out_features=1000, bias=True)
  (linear3): Linear(in_features=1000, out_features=200, bias=True)
)
```

Results

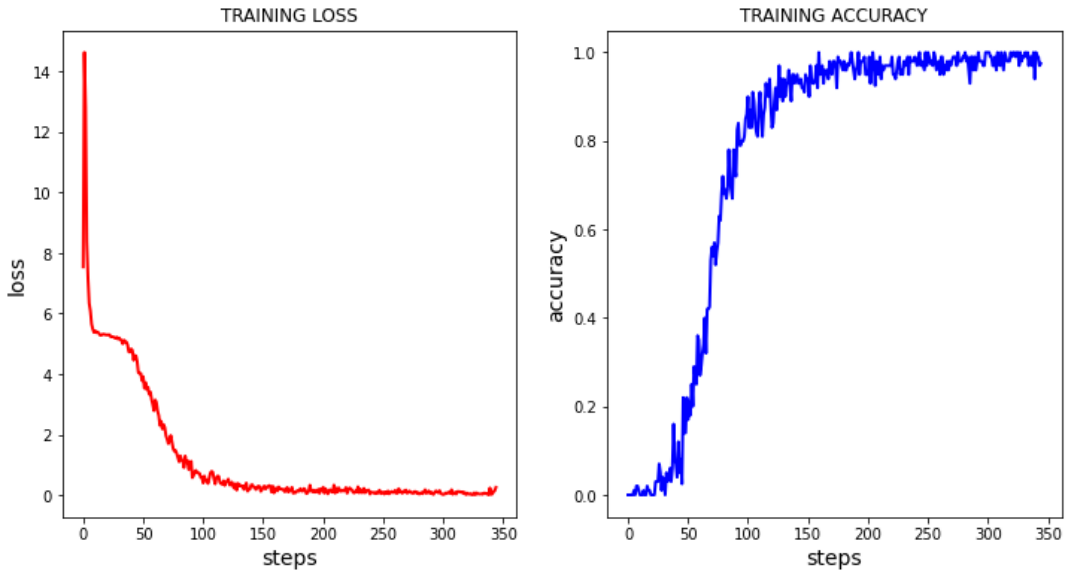


Figure 5. Classification Model #1

- Adam Optimization and Cros Entropy Loss
- Epochs: 15
- Learning Rate: 0,005
- Batch Size: 100
- Train Data Size: 2240
- Test Data Size: 560
- Time Training: 3min
- **Test Accuracy: 94,5%**

Discussion

- The spiking activity was recorded with a 4096-channel microelectrode array (MEA).
- The classification model #2 utilized the average of the first 500 ms (the full 1 s of image information consists of 0.5 s of image and 0.5 s of dark recovery).

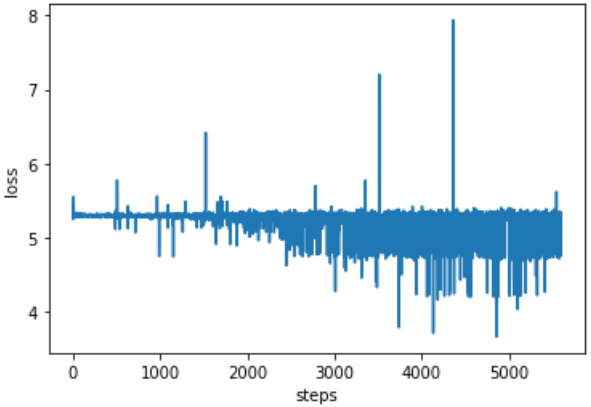


Figure 6. Classification Model #2

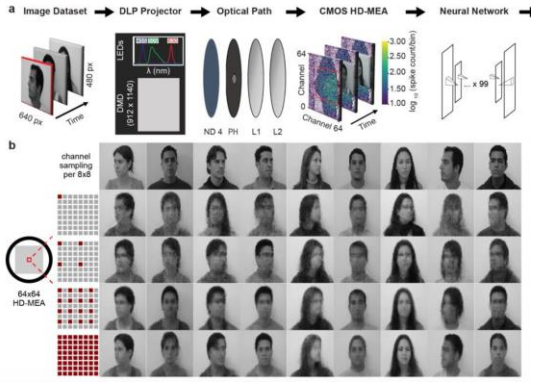


Figure 7. Neural network decoding of retinal ganglion cell Spiking activity

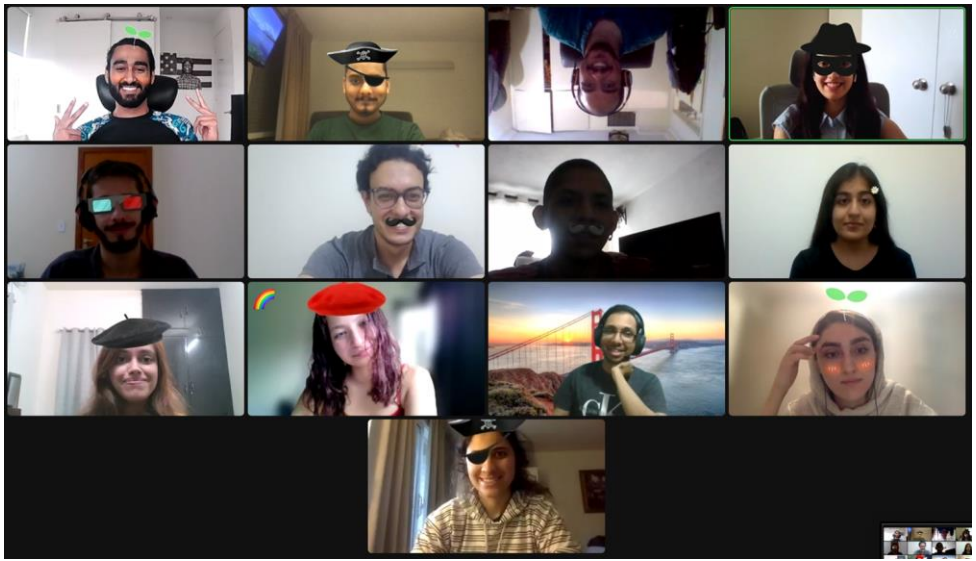
Figure 8. Spiking Activity Recorded by a Microelectrode Array

Conclusion

- Accuracy of image classifier: about 95%
- Spiking activity classifier : issue with understanding data.
- Importance of data.

Thank you

- Arefeh Farahmandi, our TA
- Dr. Luiz Pessoa for mentoring throughout project work
- Subhrasankar Chatterjee, our project TA
- Waterzooi pod
- Tyler Bestler for sharing the dataset
- The Neuromatch community



References

[1]https://www.nei.nih.gov/about/news-and-events/news/scientists-discover-gene-therapy-provides-neuroprotection-prevent-glaucoma-vision-loss
Reconstruction of visual images from mouse retinal ganglion cell spiking activity using convolutional neural networks

[2]https://www.youtube.com/watch?v=KQJalmkC5sk

[3]Tyler Benster, Darwin Babino, John Thickstun, Matthew Hunt, Xiyang Liu, Zaid Harchaoui, Sewoong Oh, Russell N. Van Gelder

bioRxiv 2022.06.10.482188; doi: https://doi.org/10.1101/2022.06.10.482188

[4]https://elifesciences.org/articles/58516