Interactive Approach to Early Visual and Auditory Neural Coding:

For Use in Early Neuroscience Instruction

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Motivation

In the initial introduction to neuroscience for many students, computational neuroscience is often covered in a cursory manner. Though technical details can be daunting for some, provided insights are often counter-intuitive and so should be accessible as early as possible. The contemporary example of efficient coding demonstrates that two disparate sensory systems (vision and audition) share exceptionally similar coding strategies, though traditional approaches treat them distinctly. We developed a demo which allows students to use their own images or sounds and shows the resulting code, demonstrating an important concept of efficient sensory coding in an accessible way.

Efficient Coding Hypothesis

Using a variety of traditional techniques, we can measure what makes a neuron respond in primary visual cortex (V1) and depict that response as a receptive field.
Receptive fields are one way to describe "what" this particular neuron responds to, but not "why" they have this form.

It is now common practice in some computational neuroscience courses to take natural images (data we've evolved to process efficiently) and apply an efficient coding strategy (such as ICA) to derive Gabor filters, which reproduce the response properties of measured neural receptive fields.

Interestingly, the same coding strategy can be used in the auditory domain. Applying ICA to natural sounds produces gamma tone filters resembling the response properties of neurons that make up on auditory nerve.

This demonstrates that the brain may be using the same, or very similar, coding strategies in disparate sensory systems.

Methods

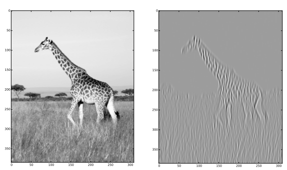
1. Natural images and sounds are collected using the phone camera/microphone. (Pictures of rocks, trees, etc. and sounds ranging from anharmonic environmental sounds to harmonic environmental sound)
2. The image or sound was randomly sampled to create tens of thousands of smaller images patches (8x8 pixels) or audio clips (100 samples in size)
3. Encoding is done using independent component analysis (ICA).
4. The resulting filters were then visualized producing the expected Gabor-like filters for the images and gammatone filters for the sounds, which match similar receptive fields measures directly from neurons in the brain.

Results

Efficient Coding Hypothesis: Neural responses in early sensory systems can be understood by their ability to reduce redundancy in the neural code for natural sensory experiences.

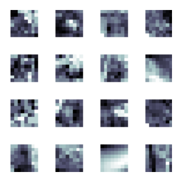
Visual Neural Code

Original



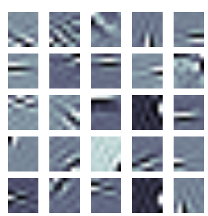
An example of an original image to be encoded.

Samples



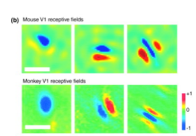
Random samples taken from the original photo.

Produced Filters



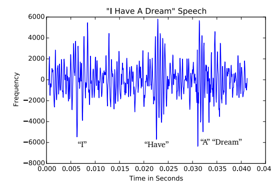
A tiling of the resulting visual filters from ICA. These filters resemble the Gabor filter-like response properties of a V1 simple cell.

Actual Filters

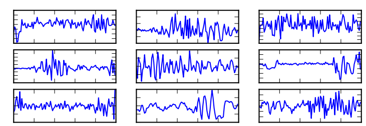


Experimentally measured visual neural receptive field filters. (Huberman, 2011)

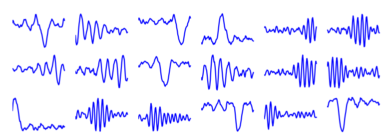
Auditory Neural Code



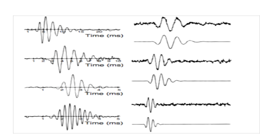
An example of an original sound to be encoded.



Random samples taken from the sound clip.



A tiling of the resulting auditory filters from ICA.Subset of these filters. A subset of these filters resemble the gamma tone response properties of neurons that make up the auditory nerve.



Experimentally measured auditory neural receptive field filters. (Lewicki, 2002)

Future Objective

This demonstration will be ported to Android to create an interactive mobile phone application.

Using the phone's built-in microphone and camera, students will be able to see the effect of images and sounds from their immediate environment on the resulting visual and auditory filters, and compare those filters to real neural receptive fields.

Conclusion

Our program is capable of interactively analyzing visual and auditory scenes using the same efficient coding method — in this case, ICA. We recreate the expected neural receptive fields and observe, as expected that by changing the images and sounds, there is a change in the resulting neural code.

References

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