Demonstration of Efficient Visual and Auditory Neural Coding

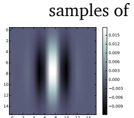
Suzanne Greenwood[1,2], Mary Makarious[1,2], Griffin Moe[3], Mark V. Albert, PhD[3]
[1]Department of Biology, Loyola University Chicago
[2]Bioinformatics Interdisciplinary Program, Loyola University Chicago
[3]Department of Computer Science, Loyola University Chicago

Motivation

The brain exhibits similar computations in different areas. Because of this, it is more important to understand how the brain computes as opposed to what each area of the brain does. This program mimics the computation of the brain to demonstrate the way in which the brain encodes visual and auditory information, and emphasize how similar they are.

Abstract

Linear filters resulting from analysis by efficient coding methods are readily visualized as receptive fields. These receptive fields are generated after analysis of random samples of the original image.



The visual filter to the left illustrates the vertical nature of the neuron and where the strongest neural response would be.

Using an efficient coding technique, the objective was to demonstrate that the computation that occurring in both the visual and auditory cortices are very similar and that the brain processes these two types of information similarly. Efficient coding is not like coding on a computer. Instead of minimizing the number of 1s and 0s, only the 1s are being minimized. Similarly, the goal is not to minimize the number of neurons, just focusing on code with minimal neural spikes.

Methods

1. Natural images and sounds were collected. These are samples found in nature. (Pictures of animals or the sound of rain)
2. The image or sound was broken down to several smaller patches. An efficient coding method, known as ICA, was used. Breaking it into individual components for analysis would produce similar receptive fields produced in both the visual and auditory cortices.
3. Filters were generated. (Gabor-like filters for the images and gammatone filters for the sounds) The filters produced represent the areas of high neural excitation and, therefore, theoretically represents how the neurons communicate and the brain processes the information.

Results

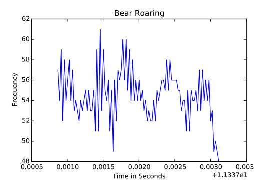
Efficient Coding Hypothesis: Theoretical model proposed as a way of understanding neural responses by reducing redundancy in the neural code for natural sensory experiences.

Visual Neural Code

Auditory Neural Code

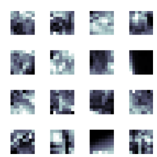
Original

Above is an example of an original image to be encoded.

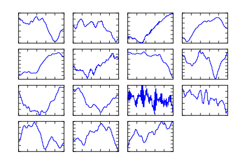


Above is an example of an original sound to be encoded.

Samples

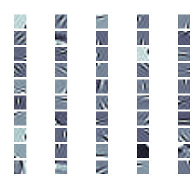


These are random samples taken from the original photo.

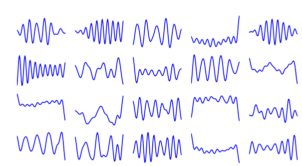


These are random samples taken from the original sound clip. These 15 graphs are random 100 millisecond clips.

Produced Filters

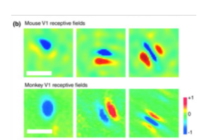


The figures above are the resulting Gabor filters from ICA. These filters resemble the response properties of a V1 simple cell.

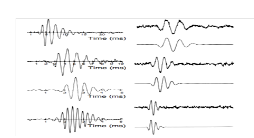


The figures above are the resulting gammatone filters from ICA. These filters resemble the response properties of neurons that make up an auditory nerve.

Actual Filters



The filter above illustrates the actual neural receptive field. (Huberman, 2011)



The figure above is the actual neural response. (Lewicki, 2002)

Future Objective

The current program requires users to have previous coding experience and to find images/sounds online and insert them into the code to see the output. A phone application would be more user-friendly. The Android application will use the camera and microphone features to capture the user's environment. Doing this would allow users to visualize how their brains encode the world around them and see how similar visual and auditory information is processed.

Conclusion

The program as it is functions in analyzing visual and auditory information using the same computation. The algorithm used doesn't produce the different results, but rather the different data that's fed in. It is very useful for demonstrating the relationship between the computation in the visual and auditory cortices, but can be improved by incorporating it into an Android application to make it more accessible to users, allowing them to compare for themselves.

References

1. Albert MV, Field DJ (2009) "Neural Representation and Coding."*Encyclopedia of Perception*, Ed. E.B. Goldstein et al., SAGE Press.
2. Huberman, Andrew D., and Cristopher M. Niell. "What Can Mice Tell Us about How Vision Works?" *Trends in Neurosciences* 34.9 (2011): 464-73. Web.
3. Lewicki, Michael S. "Efficient Coding of Natural Sounds." *Nature Neuroscience Nat. Neurosci.* 5.4 (2002): 356-63. Web.
4. Olshausen BA, and Field DJ. (1996). "Emergence of Simple-Cell Receptive Field Properties by Learning a Sparse Code for Natural Images." Nature, 381: 607-609.
5. Olshausen BA, and Field DJ. (1996). "Natural image statistics and efficient coding." Network: Computation in Neural Systems, vol. 7, 333-339

Acknowledgements

This work was supported by HHMI medical group via the "Sustaining Excellence" grant #52008101 and the Loyola University Chicago FYRE program.