MODELING CORTICAL NEURAL SURROUND EFFECTS USING DEEP NEURAL NETWORKS

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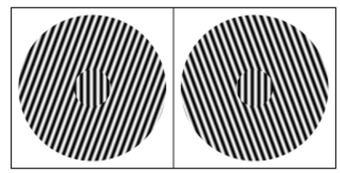
Background & Significance:

Deep convolutional neural networks (CNNs) have become popular in computer vision for applications such as object recognition. CNNs are inspired by the hierarchical structure of the brain, with multiple stages of visual processing. In recent years, it has been shown that CNNs can predict some aspects of visual cortical neural processing in the brain. However, there has been less attention to modeling contextual surround effects found in biological neurons, in which the response of a neuron to a visual stimulus in a center location is strongly influenced by the surrounding stimulus. More broadly, contextual surround effects play a role in visual perception such as visual illusions (tilt illusion shown right), and deficits have been associated with disorders.



Objectives and Approach:

It has been shown that artificial neurons in the middle processing stages (layers) of CNNs can capture some properties of neurons at the first stage of processing in the visual cortex (V1) of the brain. We identified single neurons in a CNN model that could approximately replicate the behavior that is seen in individual V1 neurons. We first mapped the feature selectivities of the individual CNN neurons, and then focused on simulating spatial surround effects in these model neurons and comparing the simulations with experimental neural studies in V1.

Outcomes & Future Directions:

We found neurons in middle layers of the CNN that showed similar selectivity to the V1 neurophysiology experiments, consistent with previous studies. We further examined surround effects and found that CNN neurons in the first layer were not influenced by the spatial surround. But neurons in middle layers of the CNN showed suppression of the neural response for increased stimulus radius size, and some neurons showed a shift of the peak radius with lower contrast, similar to the biology. This suggests that multiple layers of the CNN can approximate some of the contextual surround nonlinearities found in neurophysiology studies. In future work, we will quantitatively examine the population of CNN neurons across a wider range of center and surround stimuli. The approach can be used to identify models of the brain that capture richer nonlinear contextual effects and are more similar to biological visual processing.

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