Surround Modulation: A Bio-inspired Connectivity Structure for Convolutional Neural Networks

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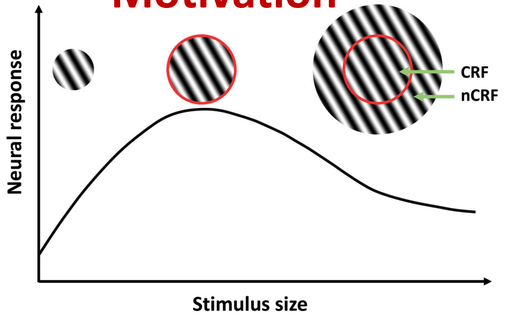
NEURAL INFORMATION PROCESSING SYSTEMS

Motivation

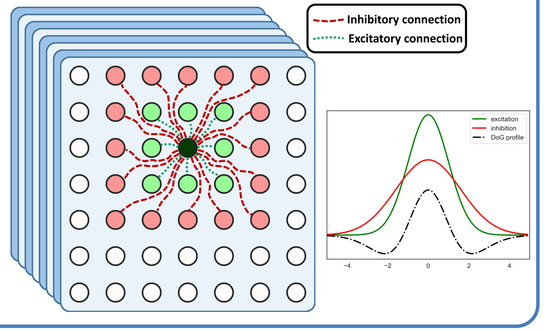


- The **classical receptive field** of a neuron is determined by the region of sensory space where stimuli elicit neural responses
- **Convolution kernel** mimics the role of the receptive field concept in CNNs
- The classical receptive field of a V1 neuron is surrounded by a **non-classical receptive field** in which the **stimuli can modulate** the response of that neuron
- The surround modulation effect is maximized when the center and surround carry **similar features**
- A neural mechanism featuring this modulation is the lateral excitatory-inhibitory connections existing in a specific layer of the visual cortex

❖ By implementing a simplified and bio-inspired version of surround modulation, here we introduce the concept of the **non-classical receptive field for CNNs**

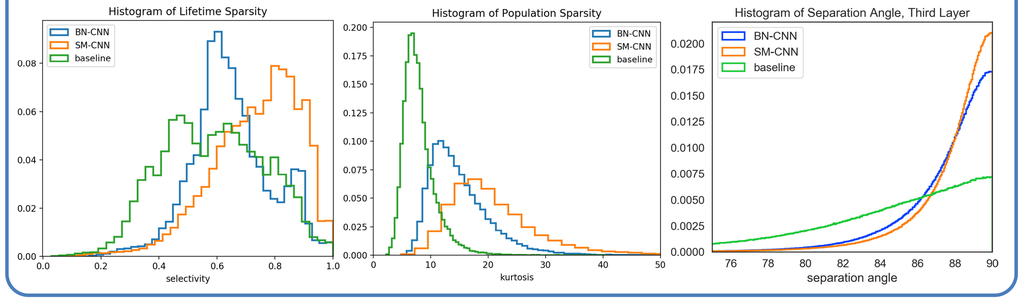
The Main Idea

- We add **lateral excitatory-inhibitory connections** between each unit of a feature map and its surrounding units in the first convolutional layer as such modulation is more common in the early visual cortex
- The **amount of modulation** depends on the distance and the neural activity levels of units
- Near neighbors **excite** each other while far neighbors **inhibit** each other based on a 2D DoG profile



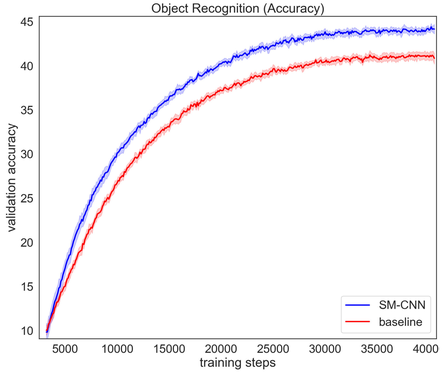
Effects on Neural Coding

- Multiple effects on neural activities analogous to those reported for visual cortex:
  - **Increase in lifetime sparsity** and **population sparsity** of units in the CNN
  - **Decrease in correlation** between the information carried by different units



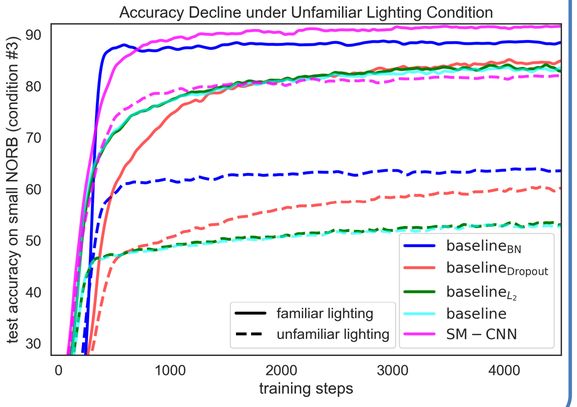
Object Recognition Experiments

Ability to reach **higher accuracy** and **training speed** when performing classification tasks on natural images



Generalization Experiments

Higher generalization when testing on different domains like changes in the lighting condition



Conclusions

- This work introduces a new bio-inspired connectivity structure for the CNNs to better resemble the structure of the brain
- As a result, the following advantages are also achieved:
  - Better classification performance and higher generalization capability
  - More biologically plausible behavior (**generalizing from fewer samples**)
  - More biologically plausible neural coding (**sparsity** and **decorrelation**)

Future Directions

- Search for better configurations of surround modulation including feedback connections from higher layers
- Incorporate surround modulation in semantic segmentation task (motivated by similar roles of surround modulation in visual system)