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

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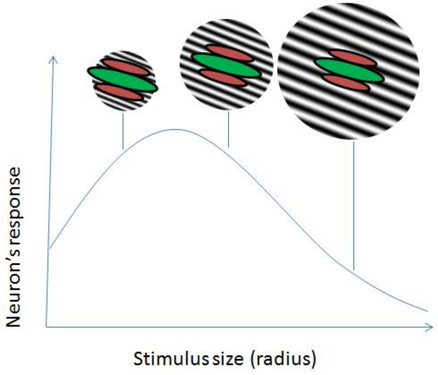
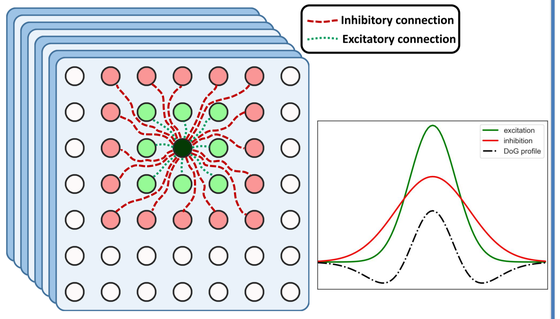
Motivation



- The classical receptive field of a neuron is the region of sensory space where stimuli elicit neural responses.
- Convolutional kernels mimic the role of receptive field concept in CNNS.
- The classical receptive field of a V1 neuron is surrounded by the nonclassical receptive field in which the stimuli can modulate the response of that neuron.
- One neural mechanism for this modulation is lateral excitatory-inhibitory connections existing in a specific layer of the visual cortex.
- By implementing a simplified and bio-inspired version of surround modulation, we introduce the concept of the nonclassical receptive field for CNNs.

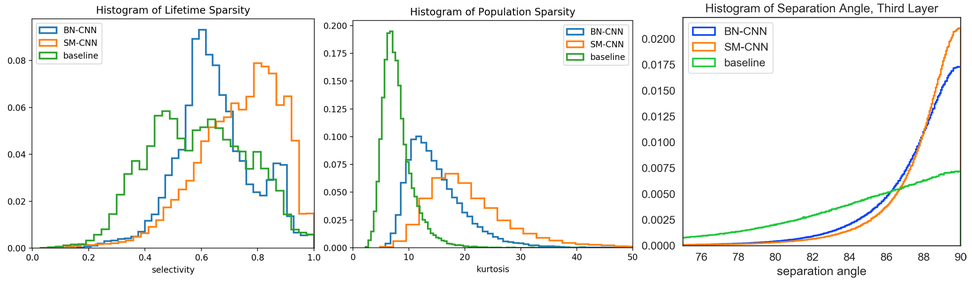
Main Idea of This Work

- Adding lateral excitatory-inhibitory connections between each unit of a feature map and its surrounding units
- The amount of modulation depends on the distance and the level of neural activity of units.
- Near neighbors excite each other while far neighbors inhibit each other based on a DoG profile



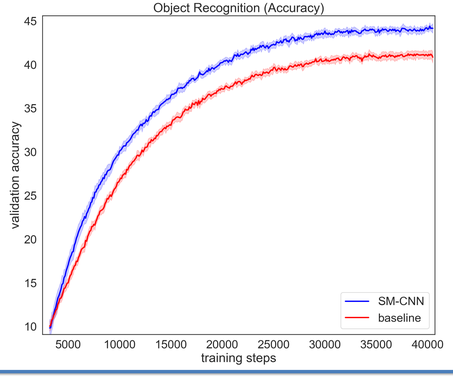
Effects on Neural Coding

- Increasing lifetime and population sparsity of units in the CNN
- Decreasing correlation between the information carried by different units



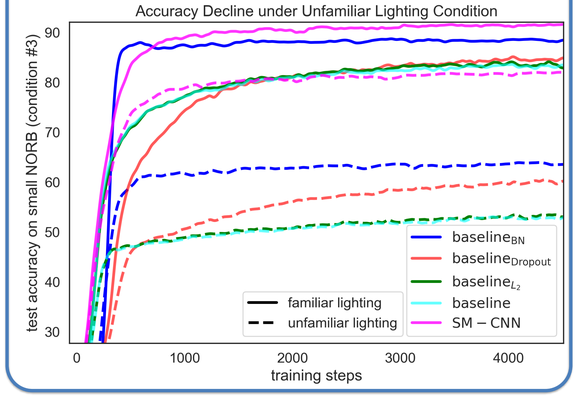
Object Recognition Experiments

The capability of reaching higher accuracy and training speed when performing classification task on naturalistic images



Generalization Experiments

Higher generalization when testing on unfamiliar domains like changing in the lighting situation



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:

- Searching for better configurations of surround modulation
- Incorporating surround modulation in semantic segmentation task motivated by the similar roles of surround modulation in visual system