Recurrent connections facilitate learning symmetry perception

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*: equal contributions

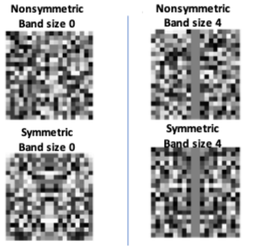
Why is symmetry challenging?

- Humans learn symmetry perception rapidly ; infants perceive it from the fourth month of development.
- Symmetry depends on **long-range relationships.**
- Assay for investigating if DNNs that are considered models of the human visual system can learn to perceive an abstract feature.

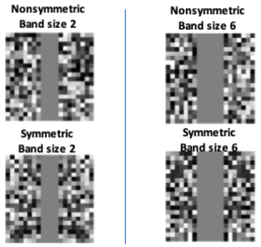
Can computational models of object recognition learn symmetry?

We demonstrate that when transfer-trained to recognize mathematical symmetry in synthetic images, DNNs for object recognition are unable to generalize outside the training distribution.

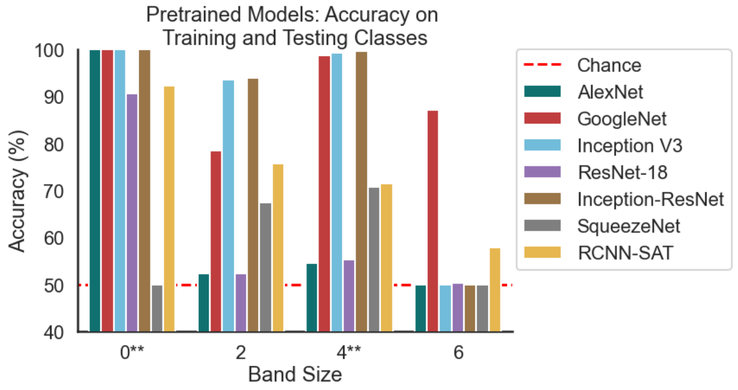
Training Data



Testing Data



Network Accuracy



Conclusion: Object recognition models are **unable to learn a general solution**

What architectures can learn symmetry?

Dilated Convolutional Neural Network

- Atrous (dilated) convolutions
- Expand the receptive field while maintaining the same number of parameters

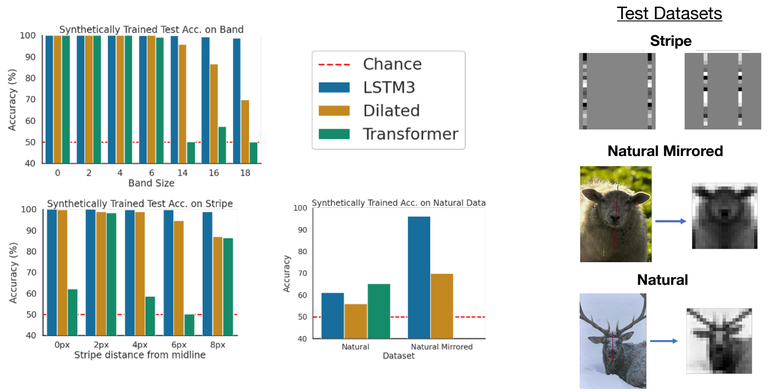
Convolutional LSTM (ConvLSTM)

- Weight-sharing across layers
- Capable of breaking long-range dependencies into sequences of local operations

Transformer

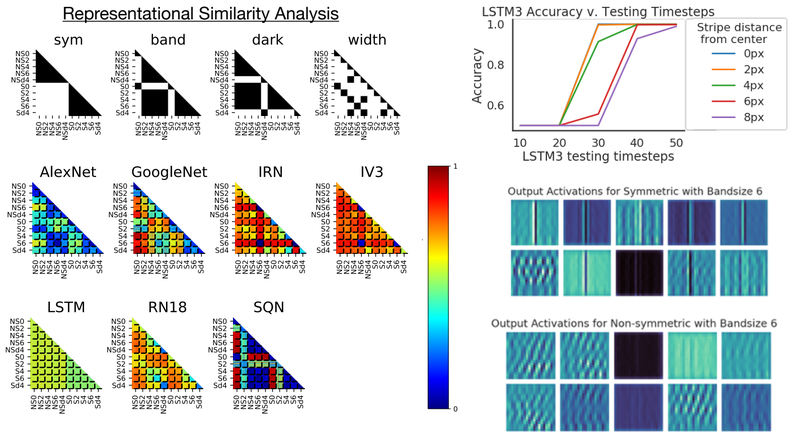
- Self-attention layers for long-range dependencies
- Pretrained on 400 million images

Cross-dataset evaluation shows that only LSTM generalizes:



Test Datasets

LSTM representations: homogeneity for symmetric samples

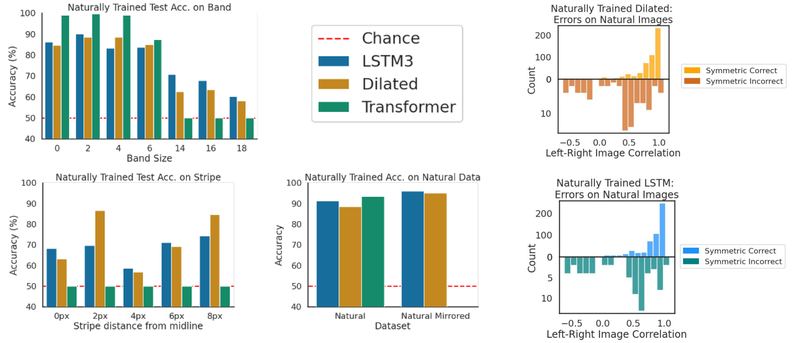


Conclusion: Recurrent connections **facilitate learning symmetry**

What is the impact of incorporating natural factors?

When trained with natural images, interfering natural factors (noise, illumination, etc) inhibit the LSTM's learned perception of symmetry, lessening the advantage over other architectures.

LSTM has less advantage over other architectures:



Conclusion: Natural factors **make learning symmetry more difficult**

Conclusions

- Networks for object recognition are unable to learn a general solution to symmetry detection, though they are considered good models for human visual processing.
- LSTMs facilitate learning symmetry perception and generalize for different categories of synthetic images.
- Additional factors involved in natural symmetry (noise, illumination, etc) interfere with symmetry perception and make learning a general solution more difficult.

Acknowledgements

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