Pathology Segmentation with Group Equivariant Networks

Jon Middleton

Supervisors: Akshay Pai, Stefan Sommer, Mads Nielsen

Innovationsfonden

UNIVERSITY OF COPENHAGEN

CEREBRIU
TRANSFORMING RADIOLOGY

Takeaways

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- There's a need for sample efficient networks in medical imaging

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- Group equivariant networks are sample efficient

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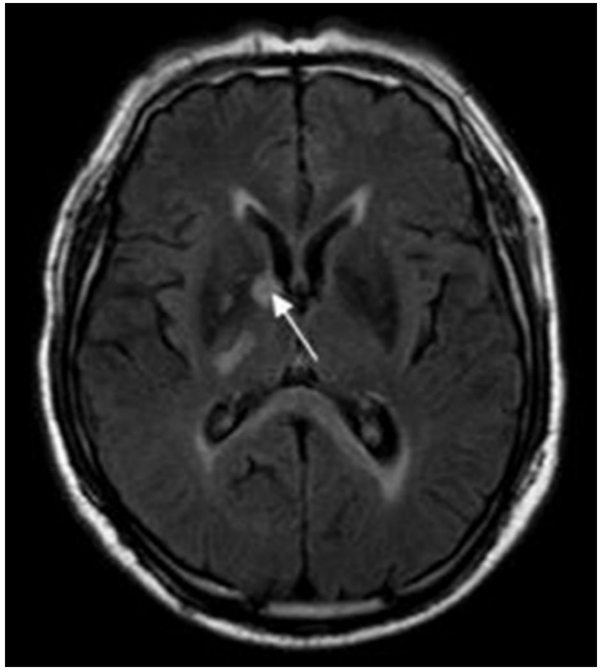
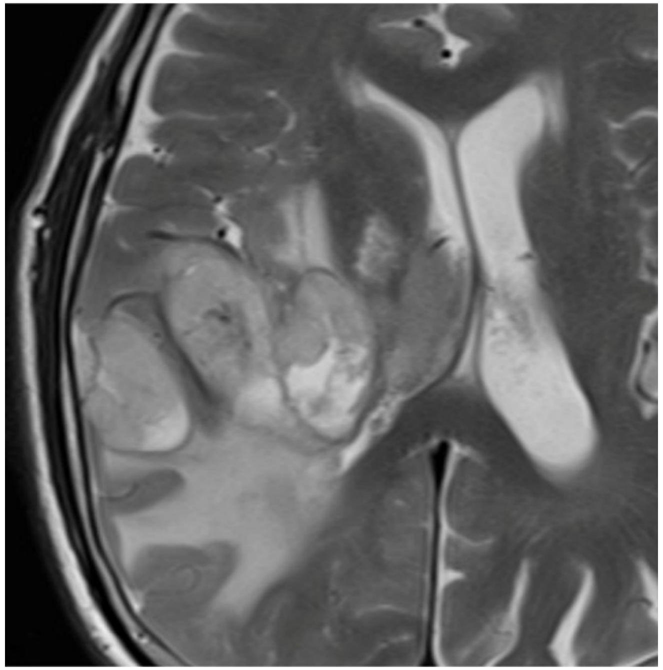
- Group equivariant networks are sample efficient
- Applications of group equivariant networks into detection tasks in brain MRIs are worth investigating

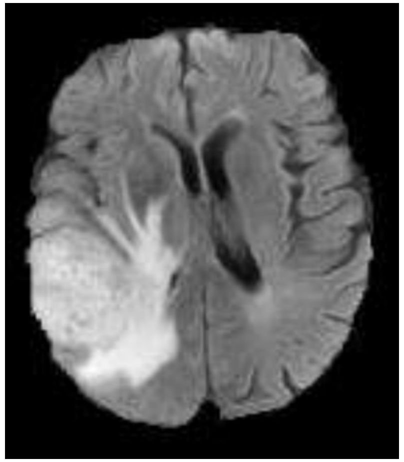
Cerebriu highlights pathologies in brain MRIs

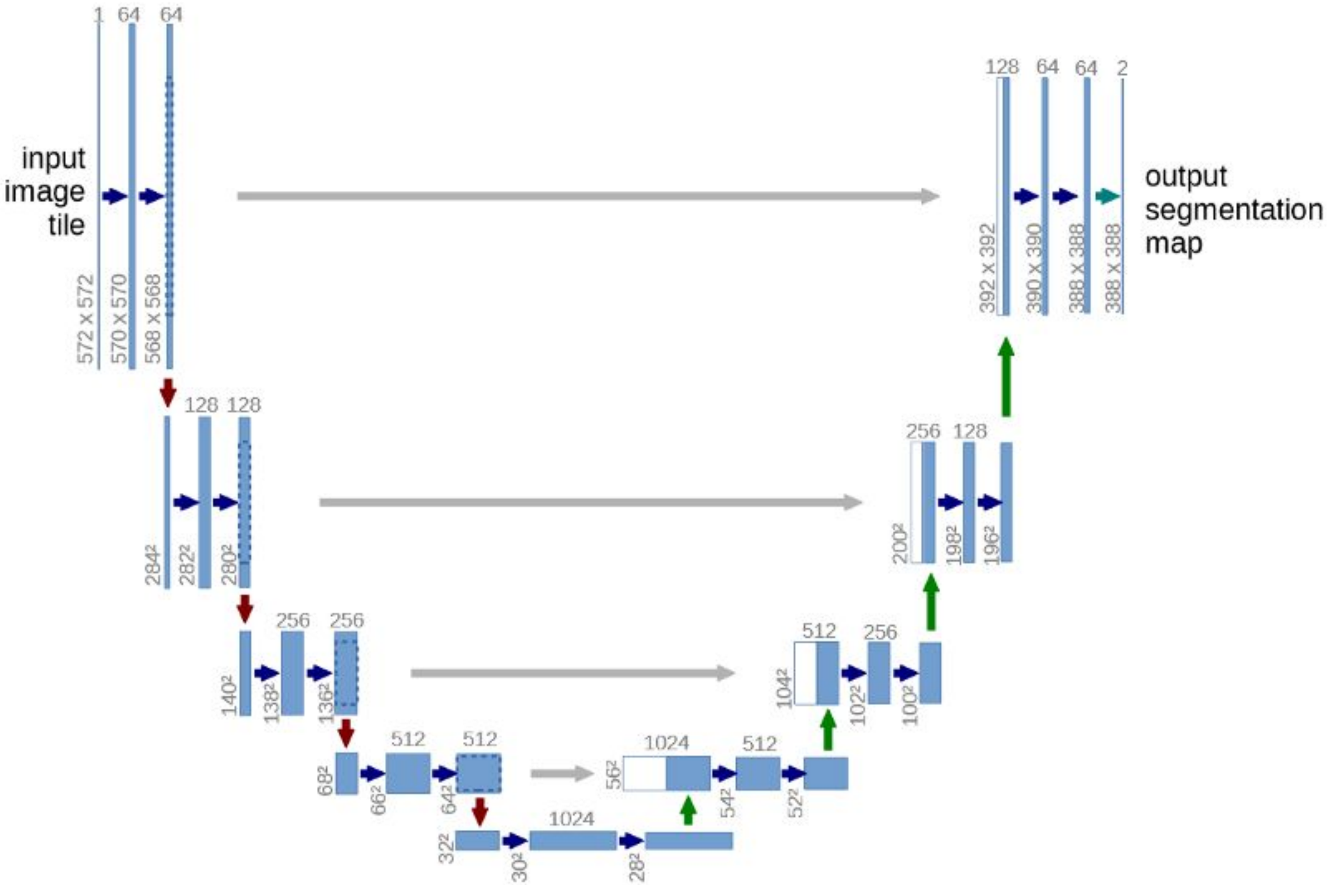


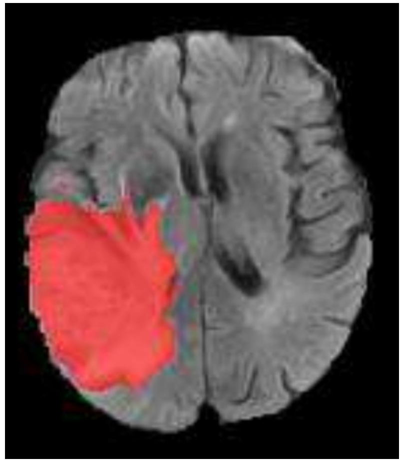


Sources: Luo et al. 2020; Renard et al. 2018; Maekawa et al. 2020

Cerebriu highlights pathologies with deep neural networks

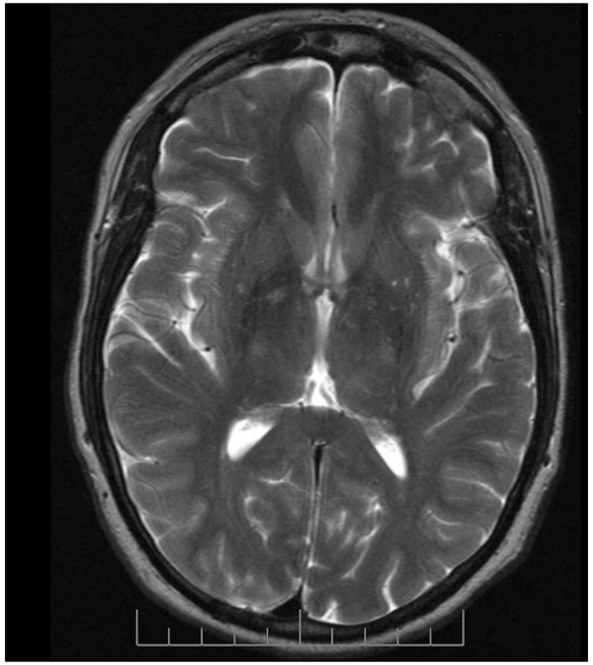






Source: Ronneberger et al. 2015

Deep neural networks are data-hungry

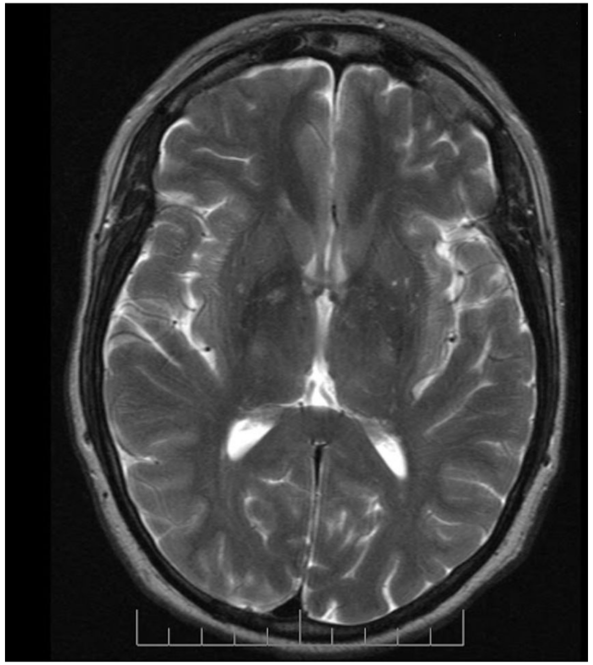


Source: https://commons.wikimedia.org/wiki/File:MRI_T2_Brain_axial_image.jpg

Deep neural networks are data-hungry

Solutions:

- *Explicit* data augmentation (e.g. data transformations)



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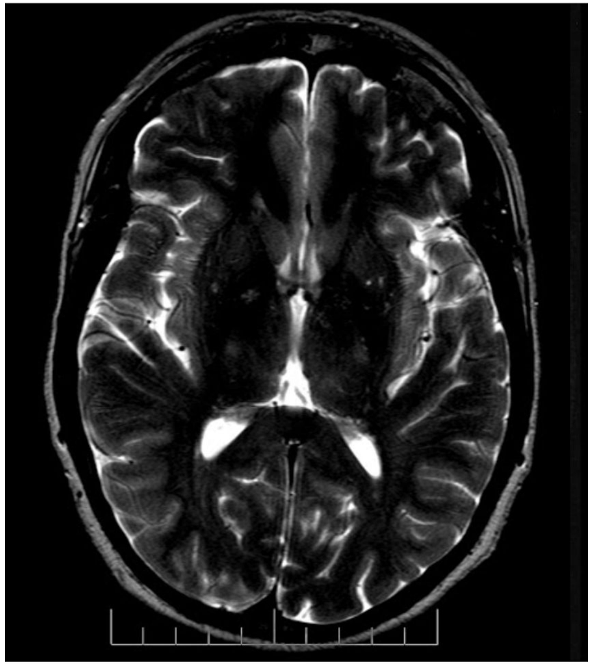

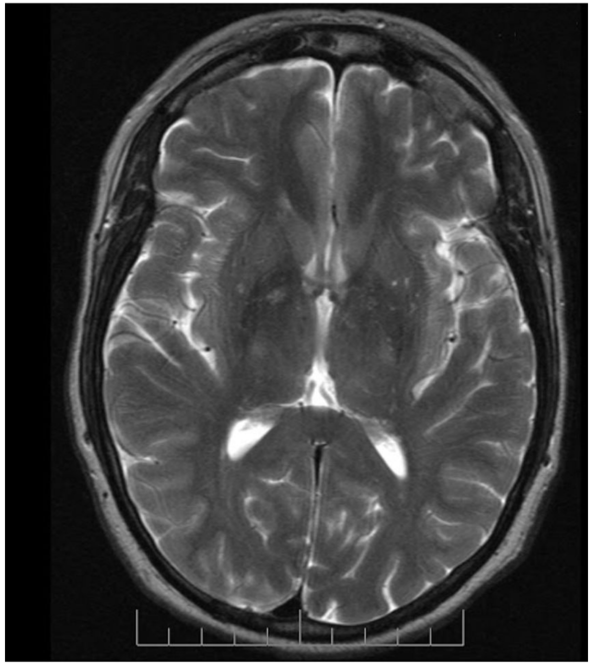

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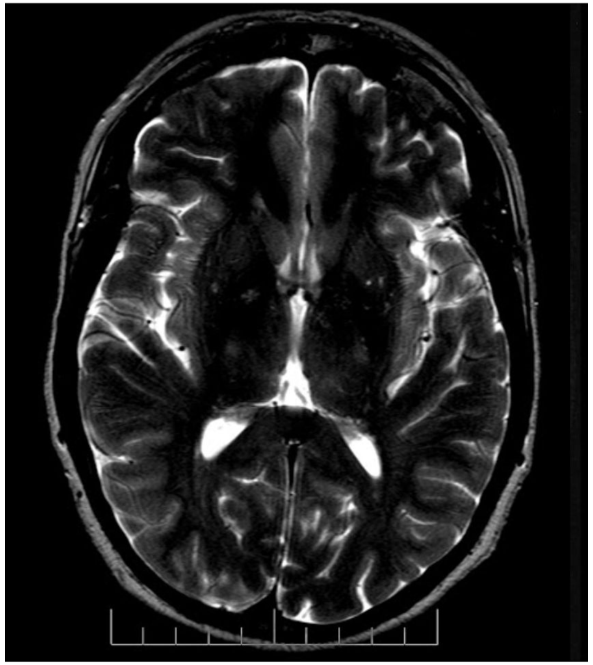
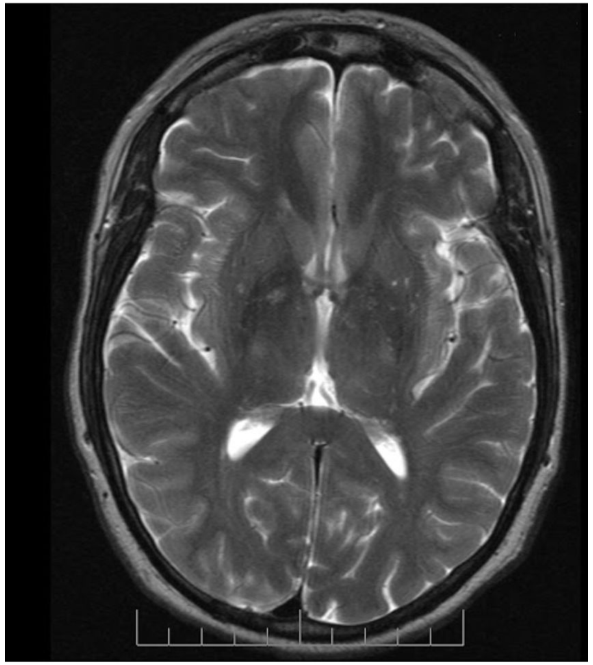
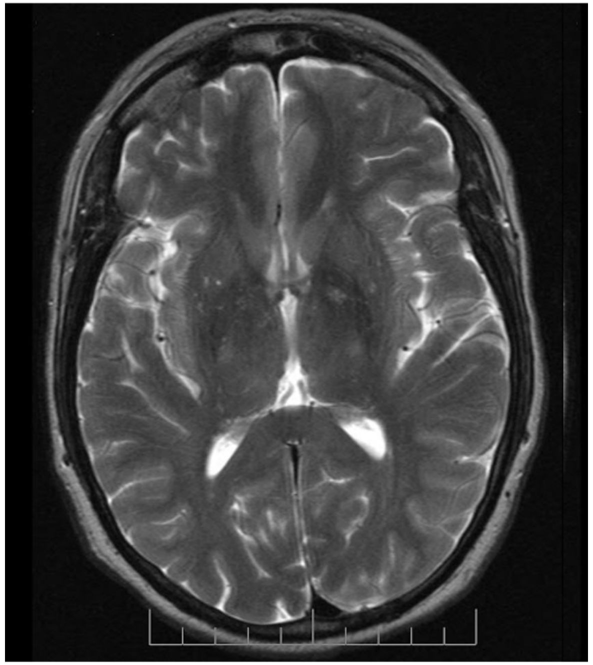

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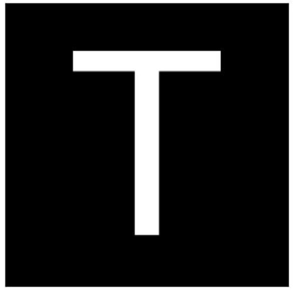
Deep neural networks are data-hungry

Solutions:

- *Explicit* data augmentation (e.g. data transformations)
- *Implicit* data augmentation (e.g. group equivariant networks)

Convolution is translation-equivariant



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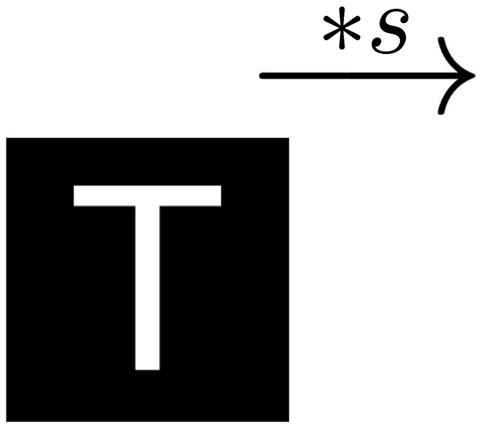

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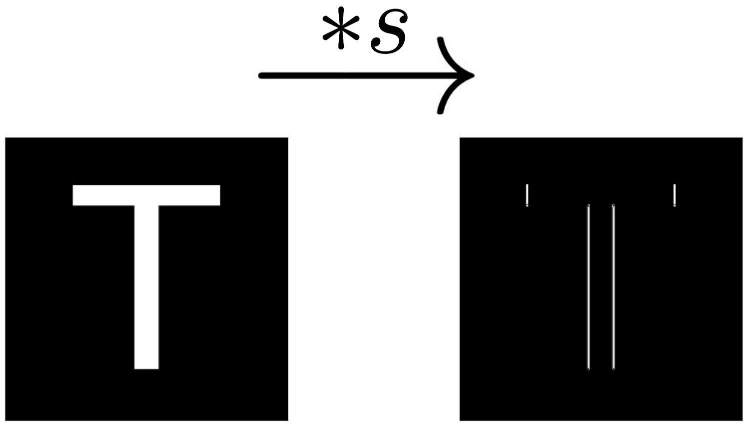

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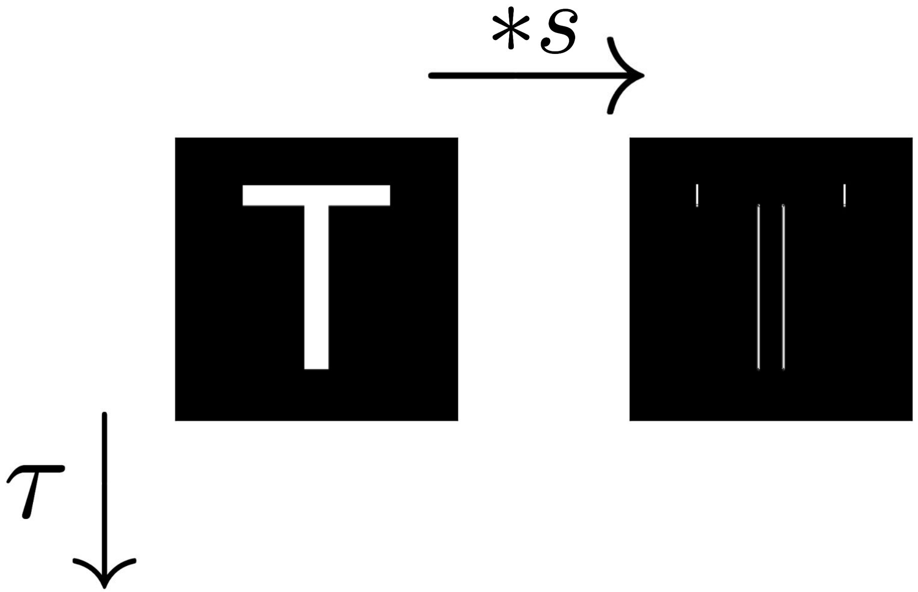

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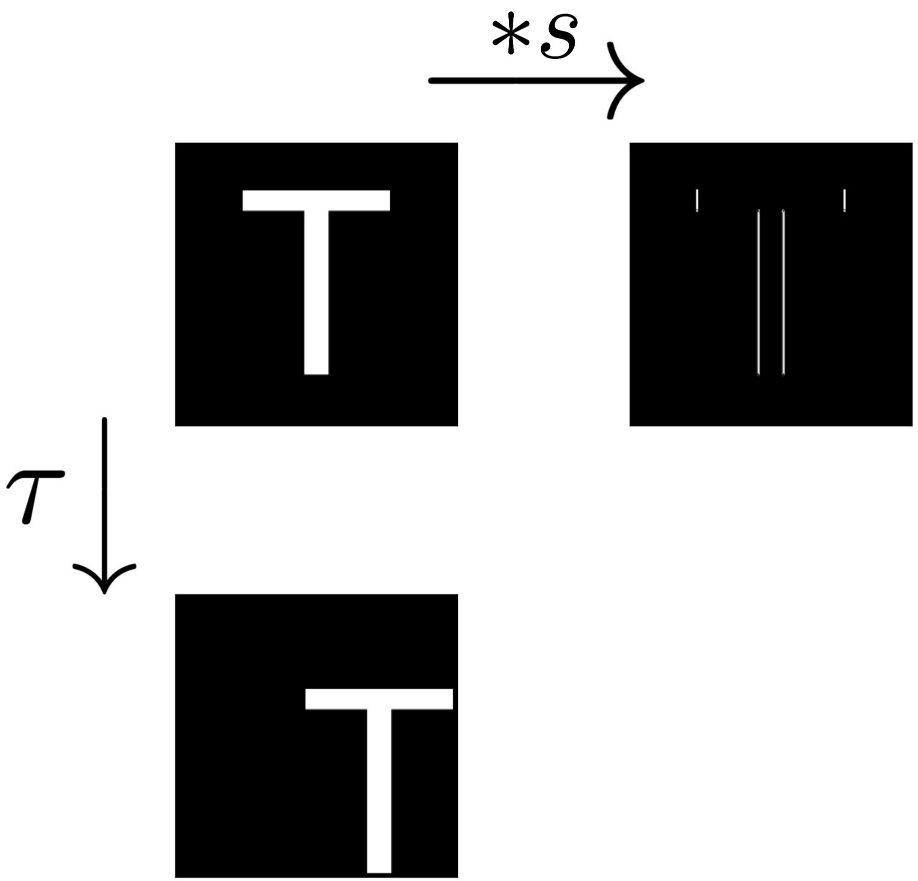

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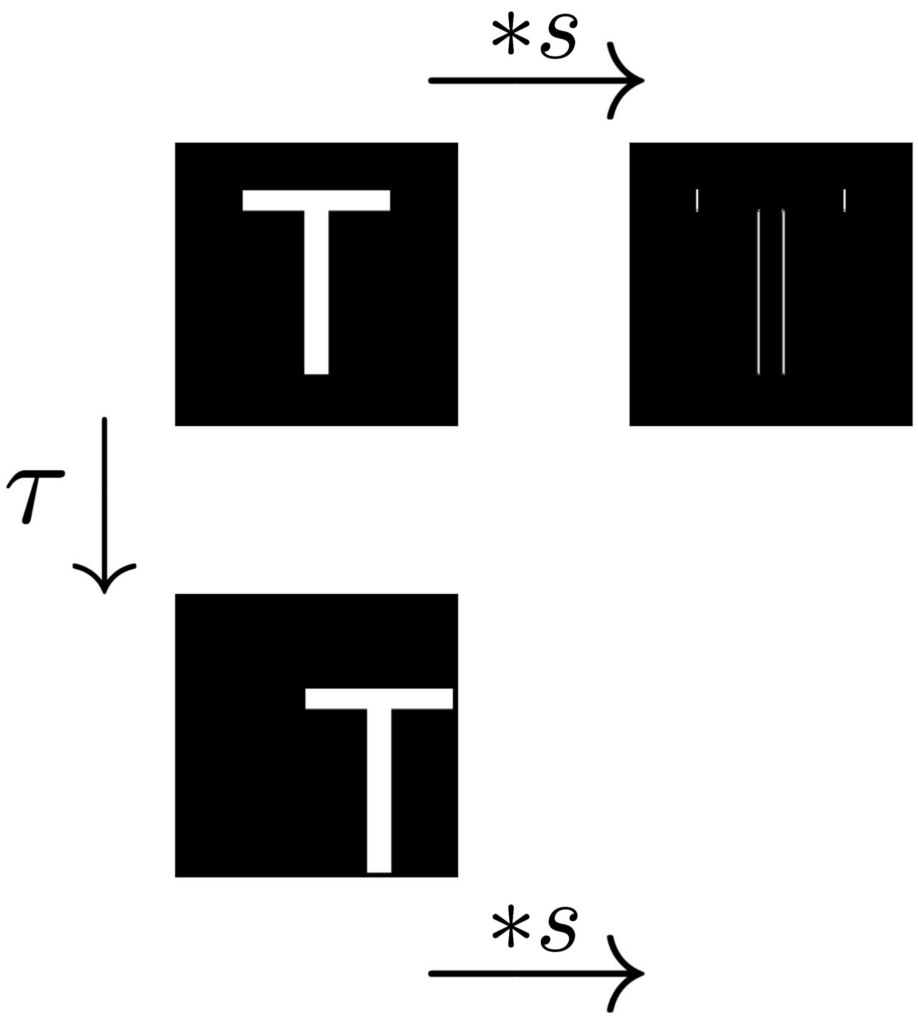

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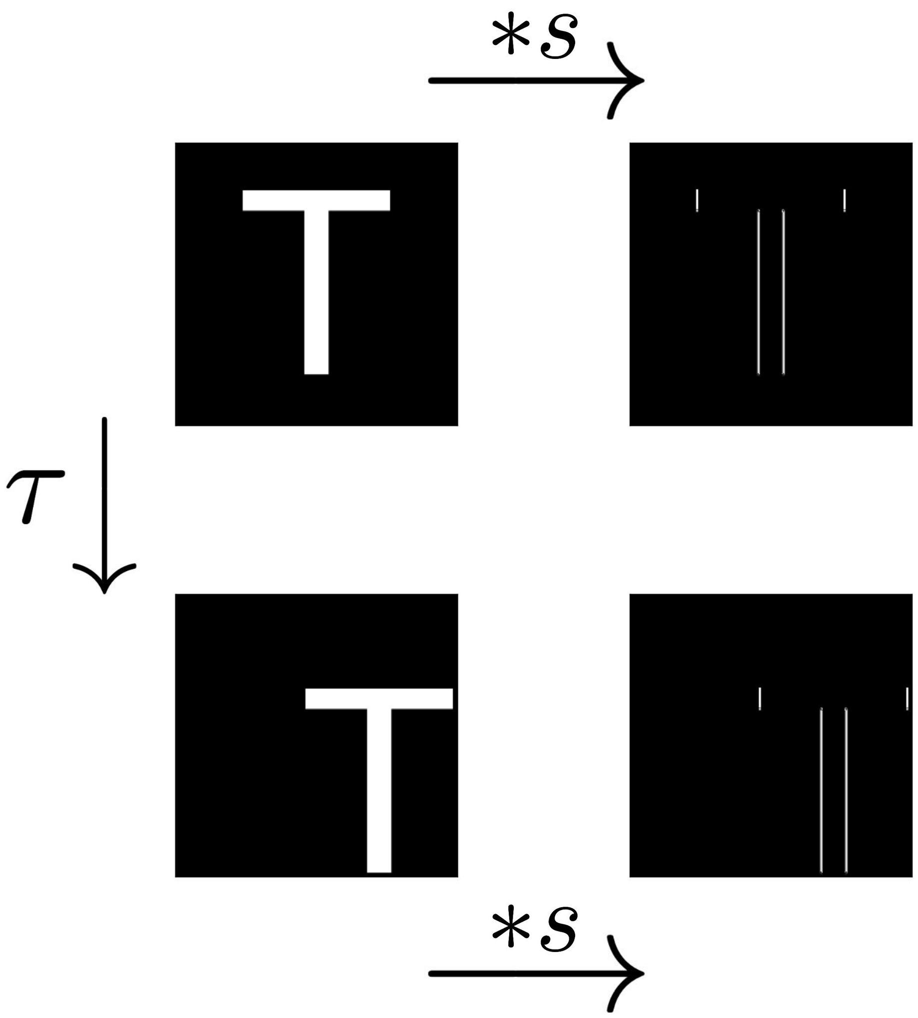

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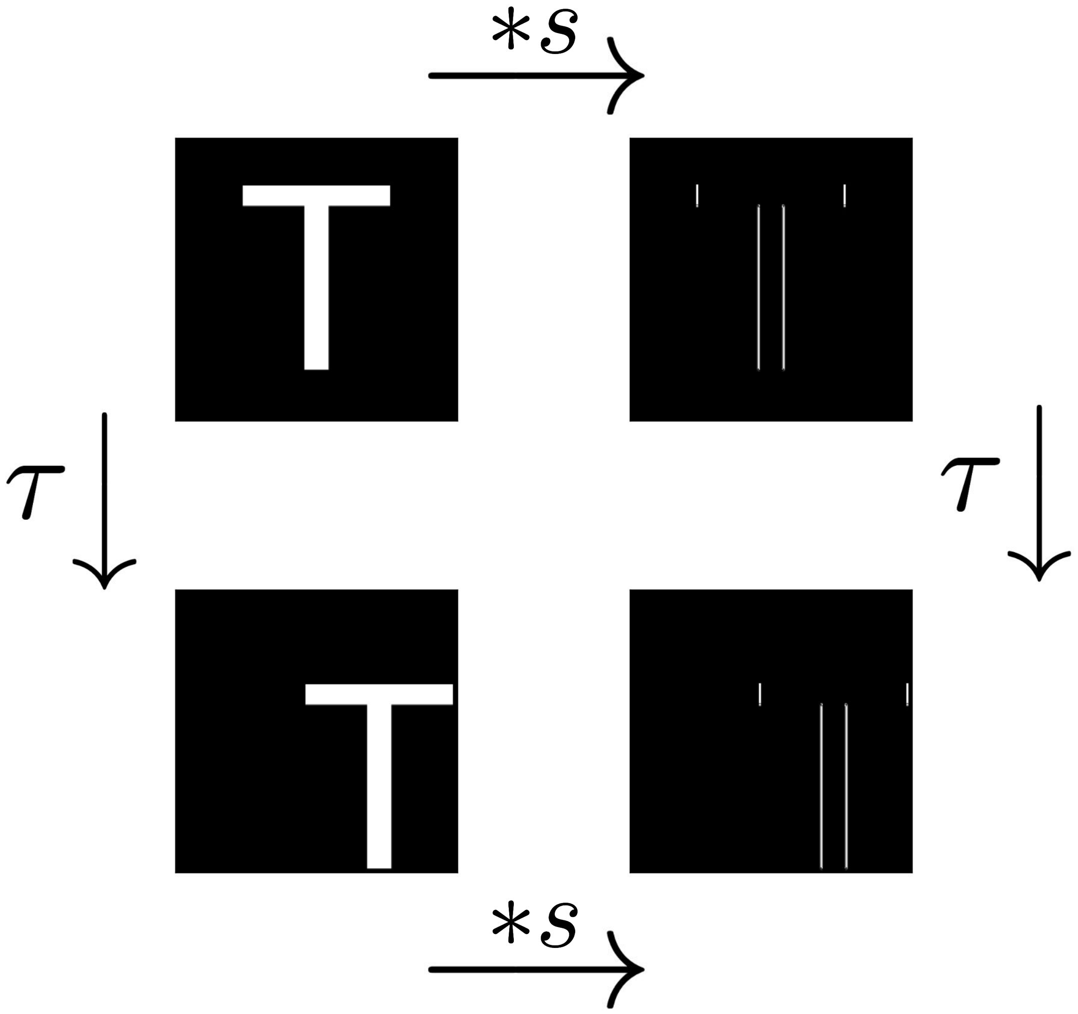
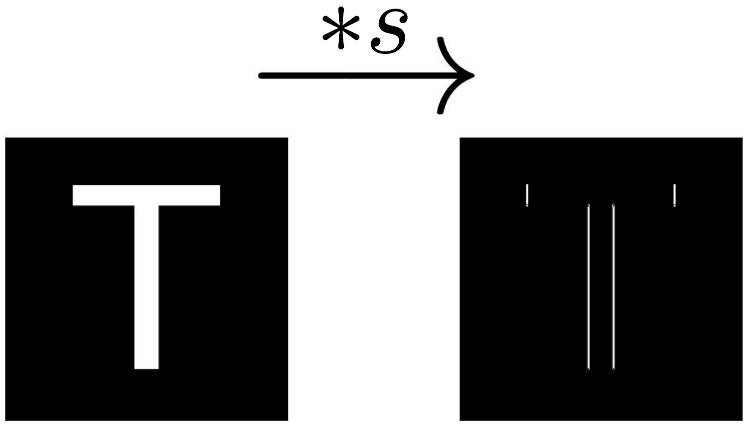


Convolution is *not* rotation-equivariant



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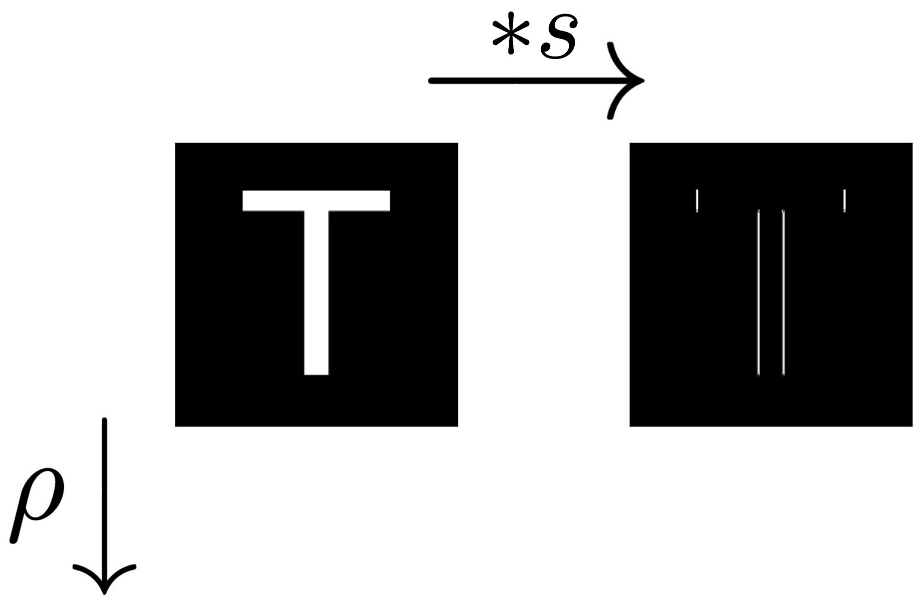

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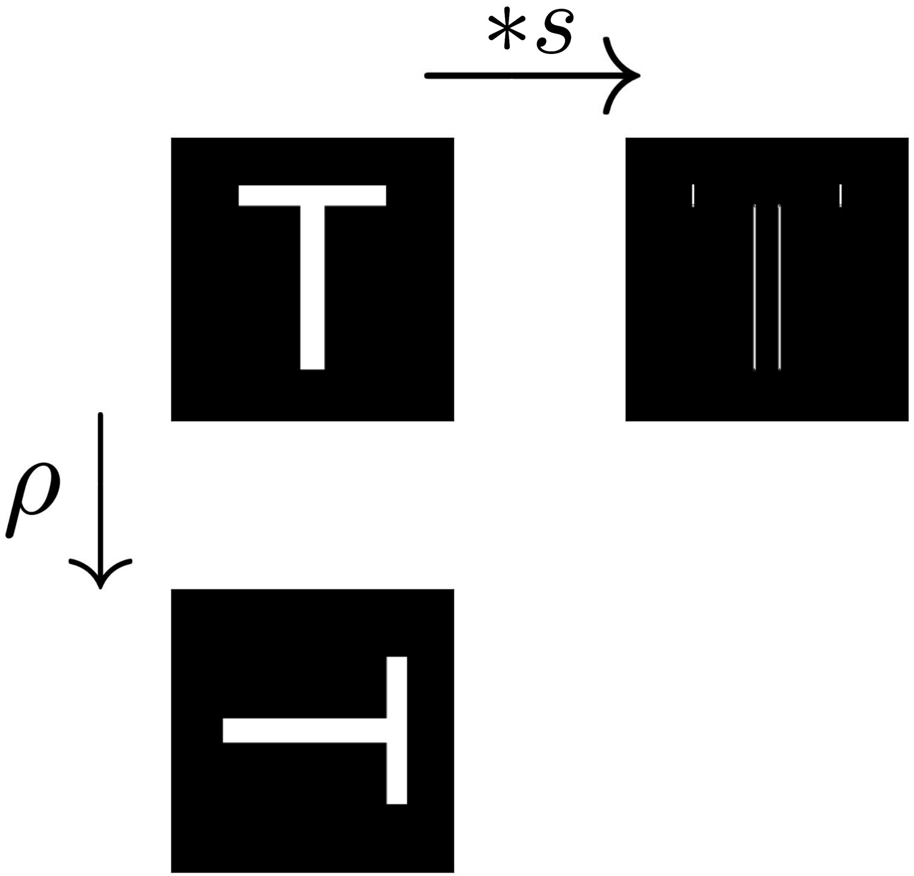

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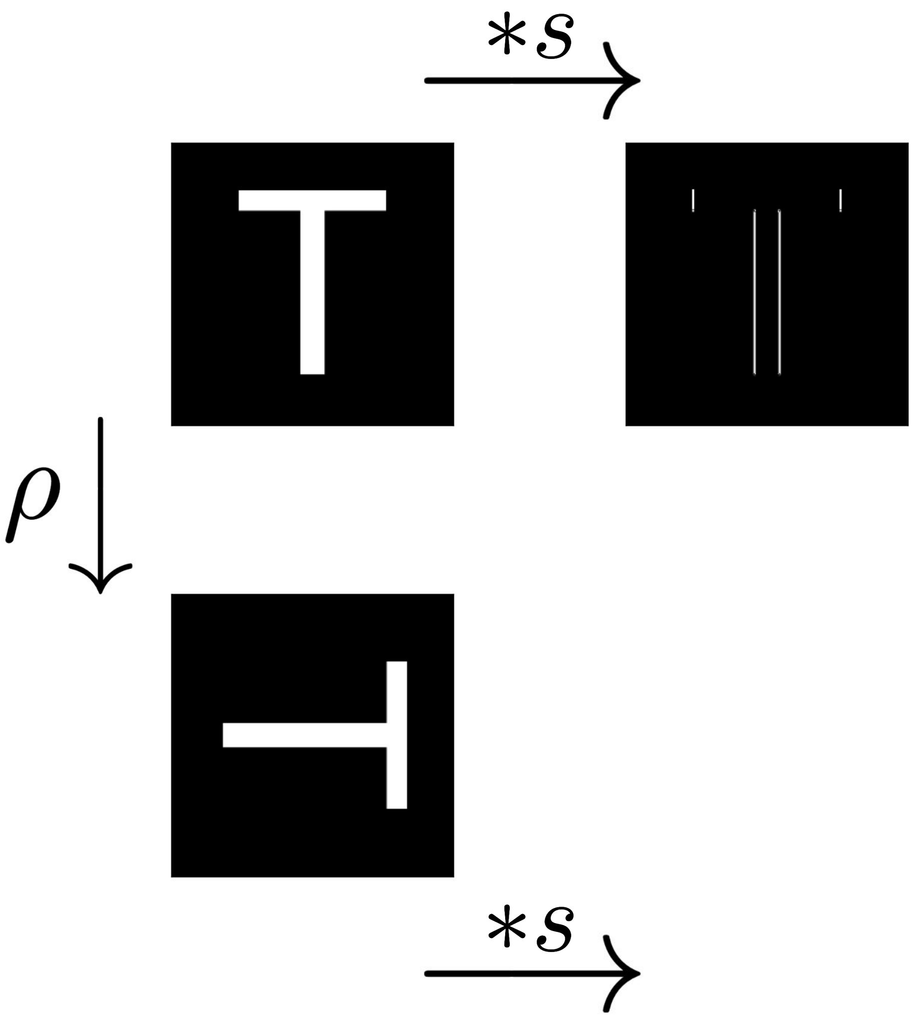

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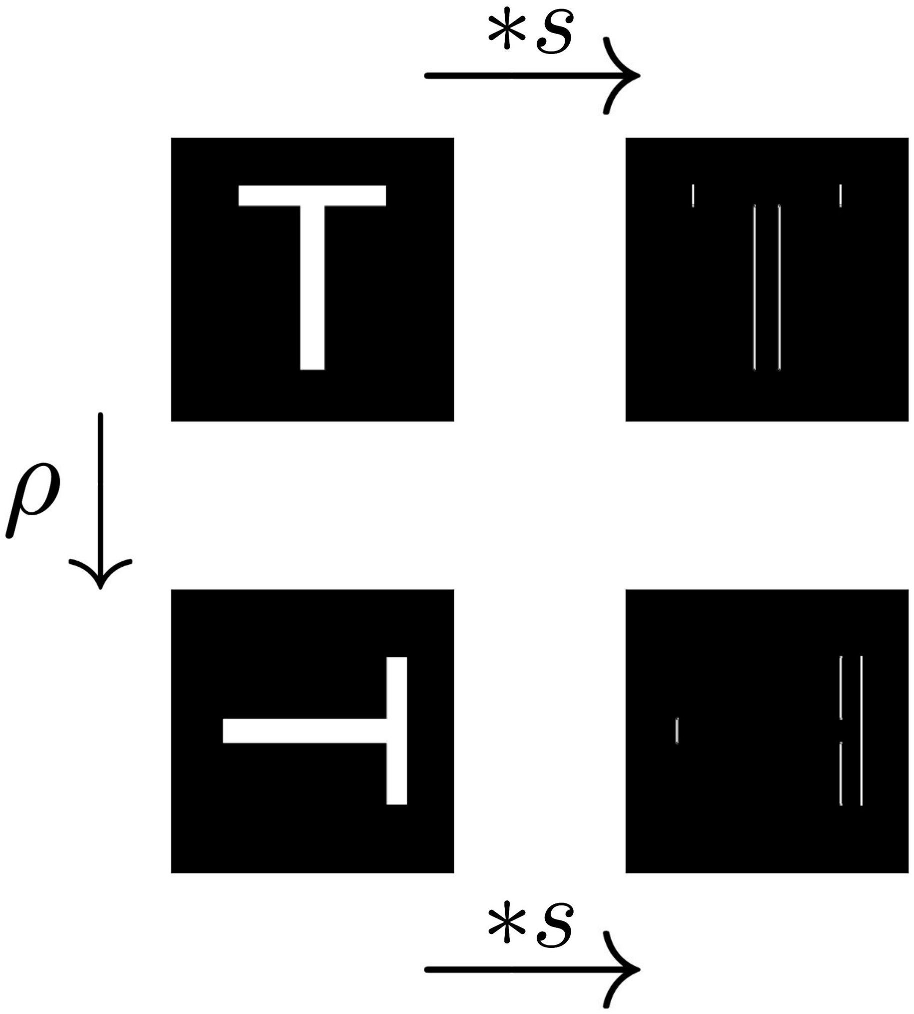

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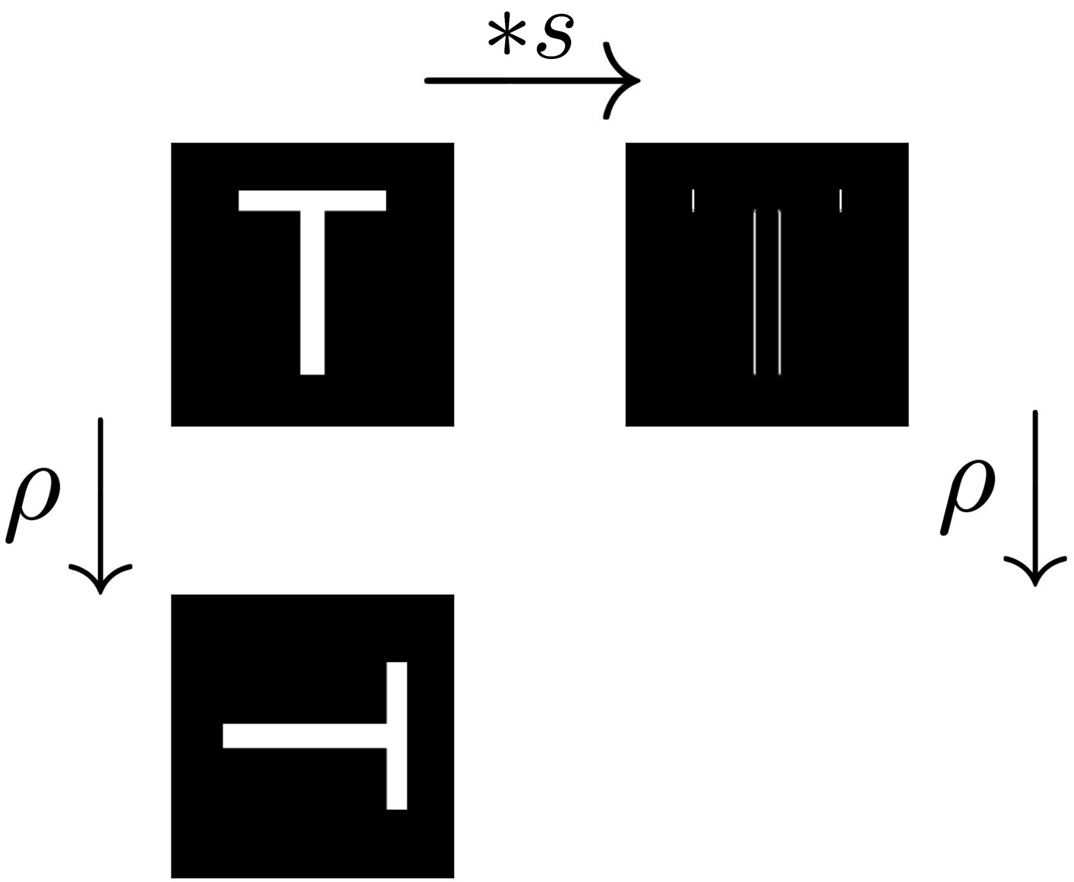

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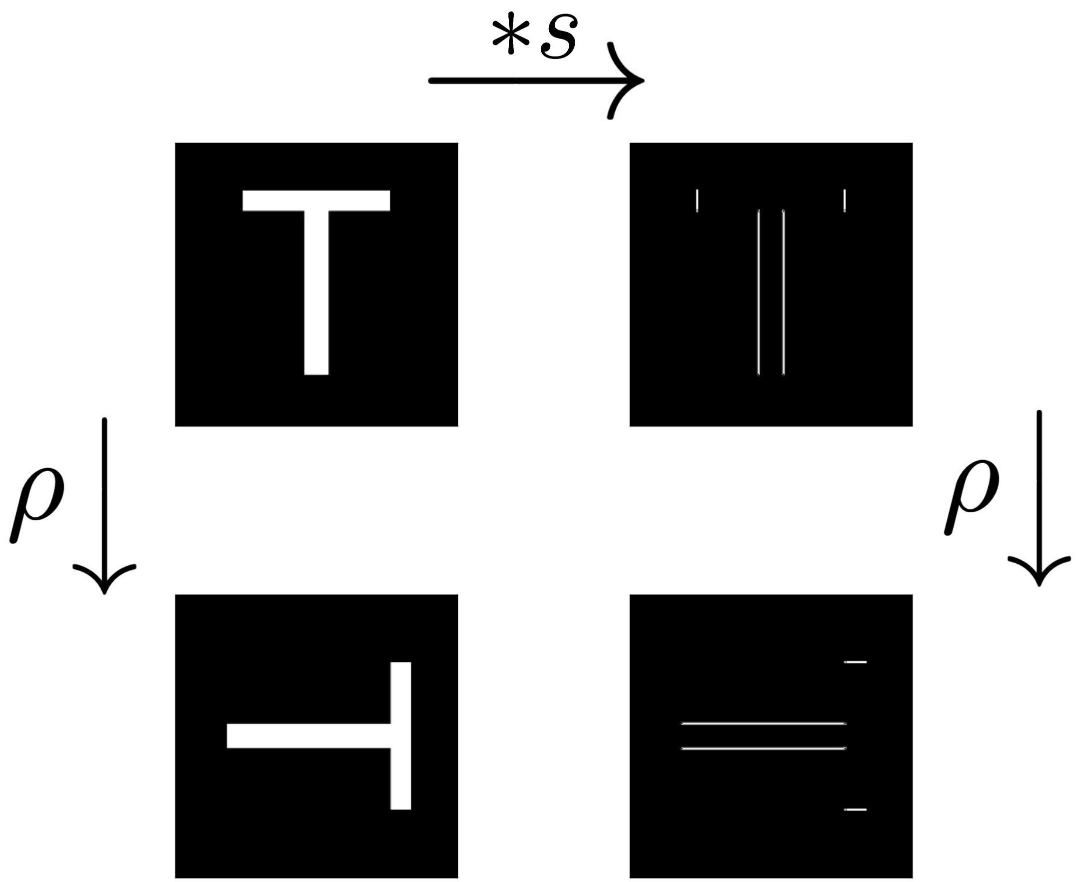

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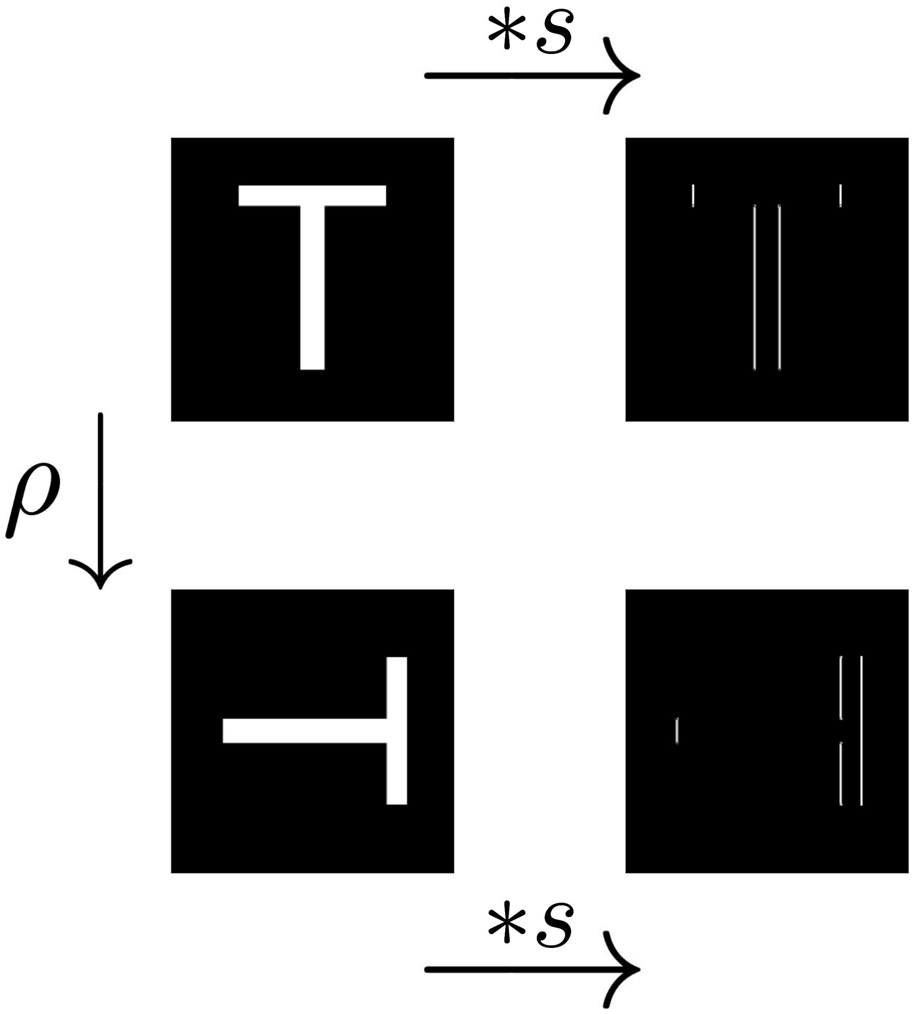

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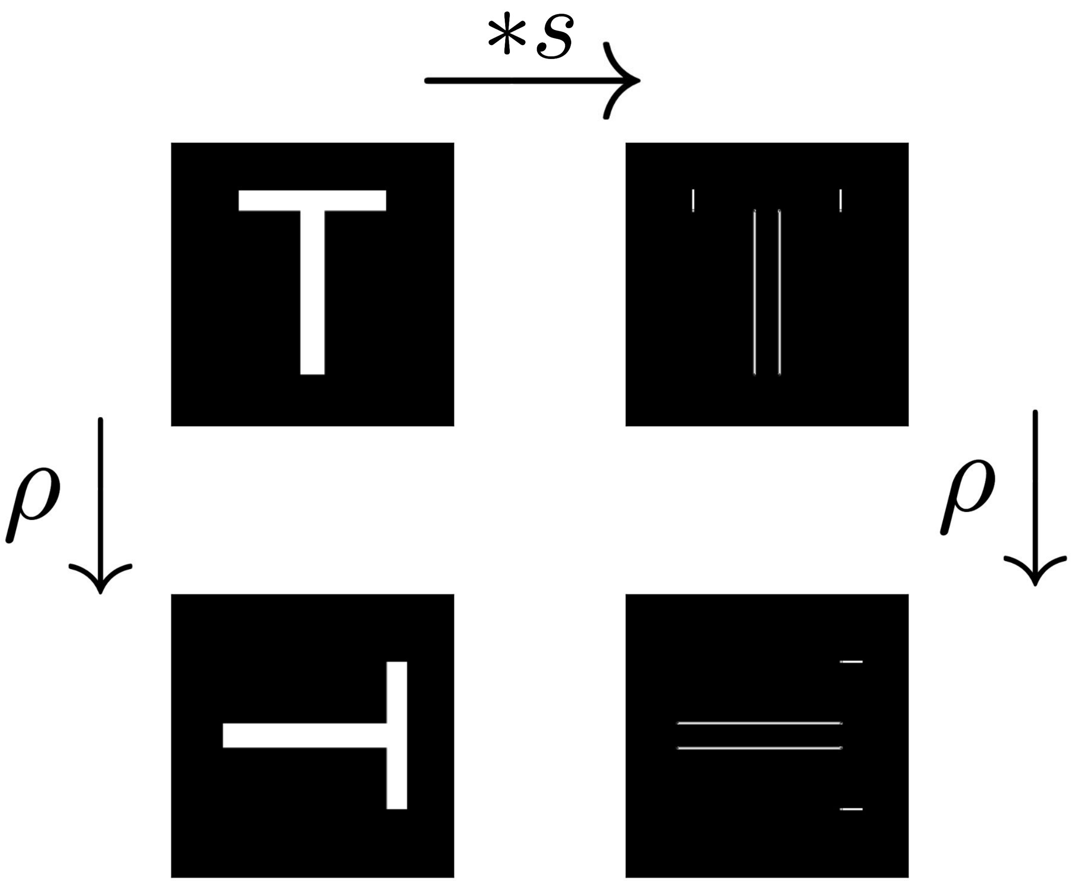
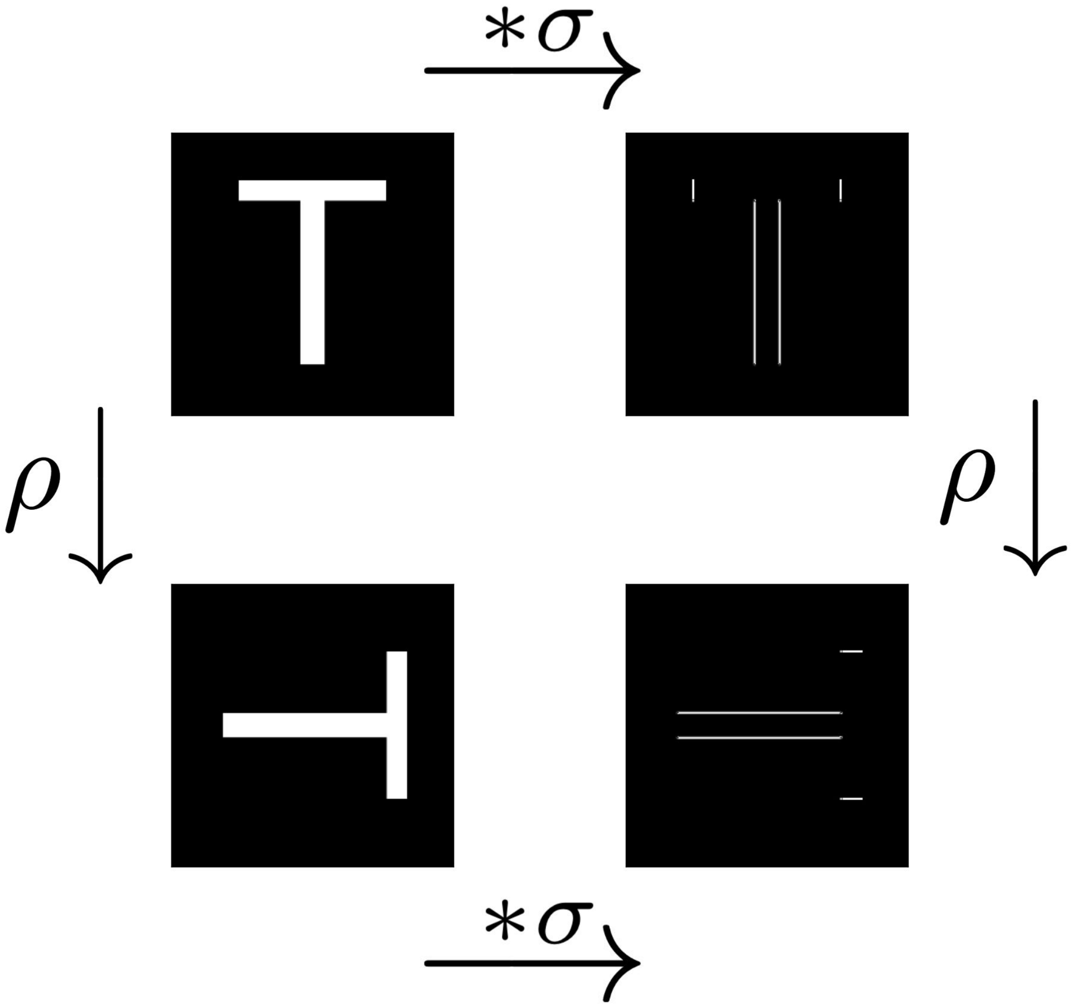
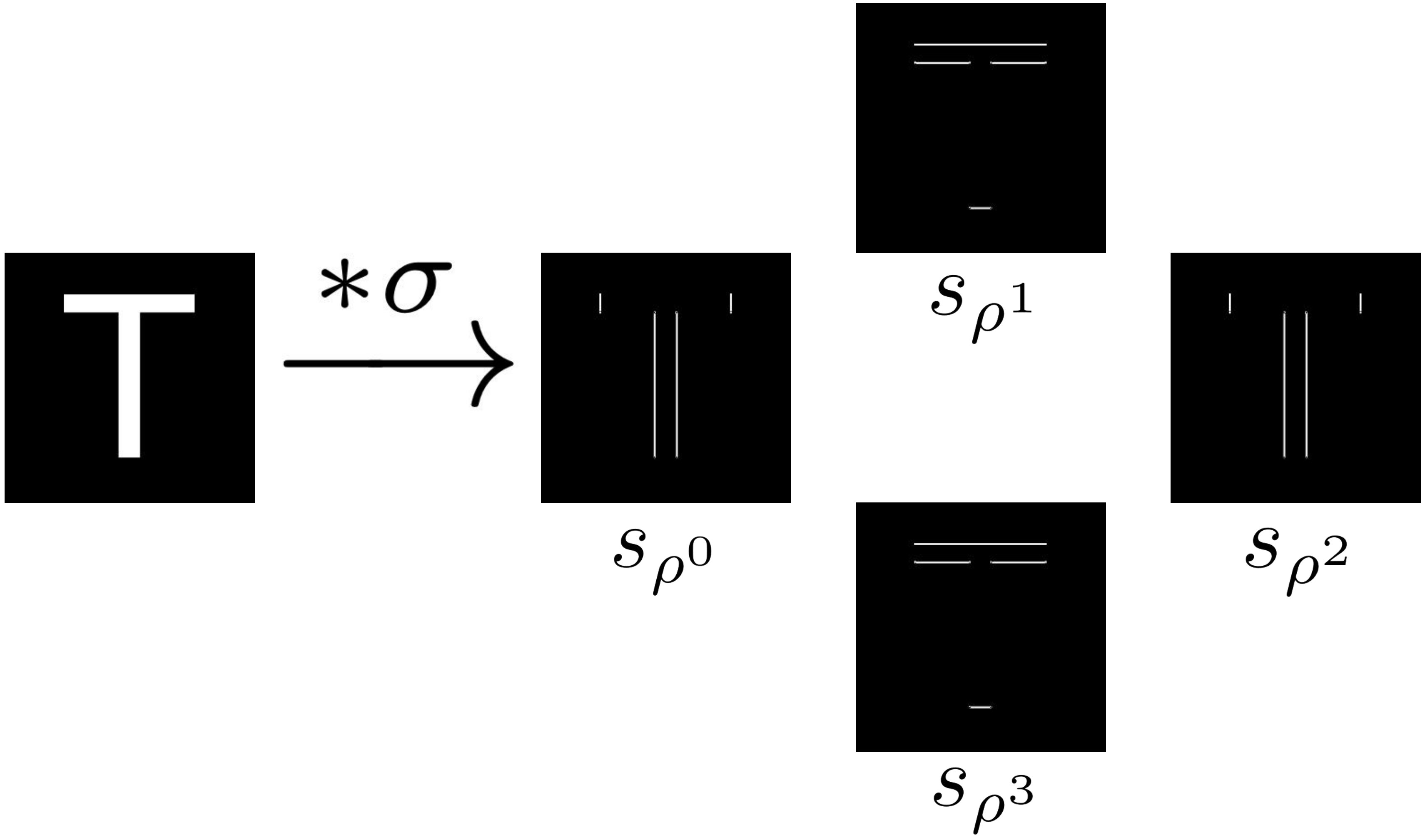


Problem: convolution and rotation are incompatible, in general

Rotation-equivariance is achieved with restructured filters



Convolution with a finite-group equivariant filter



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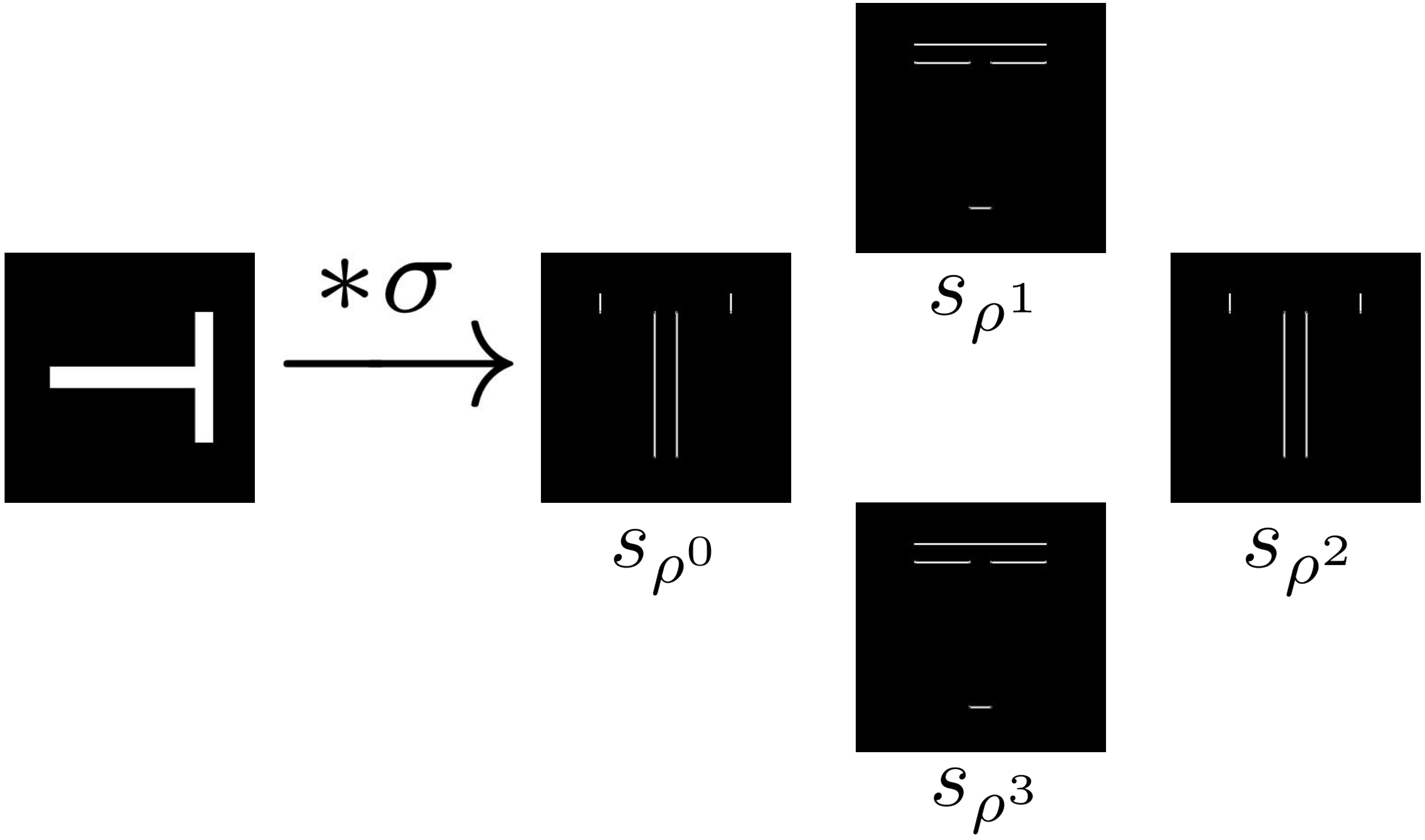

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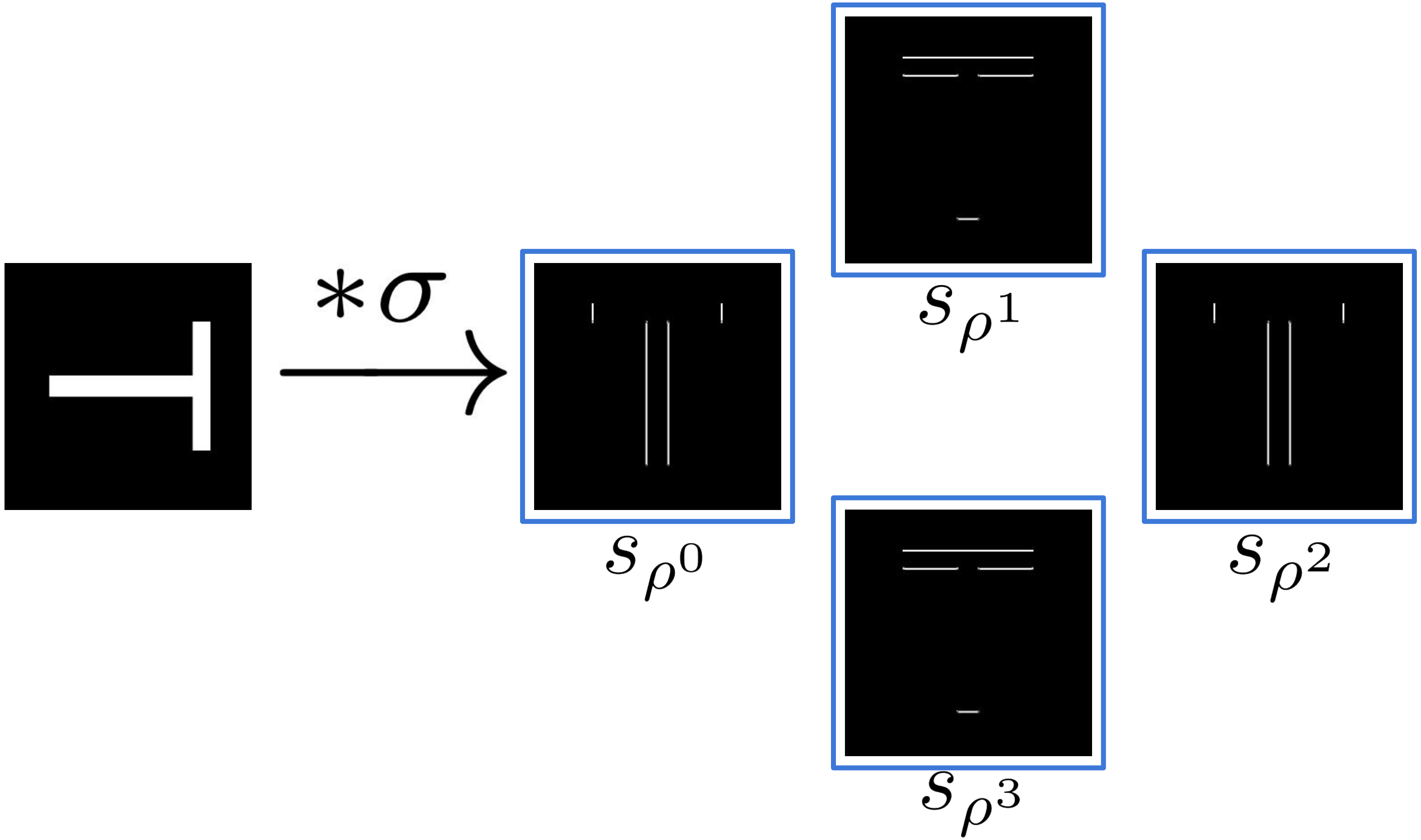

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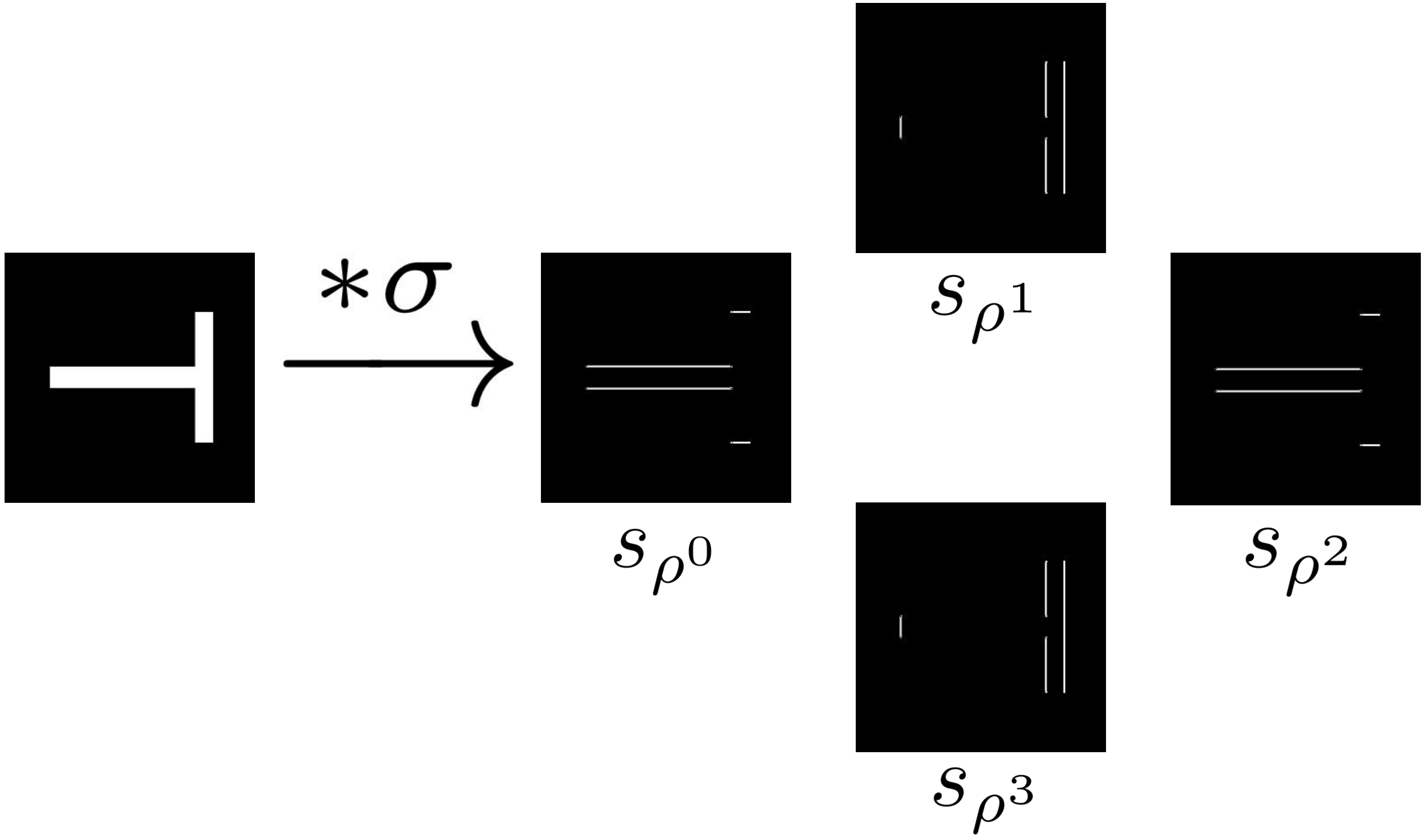

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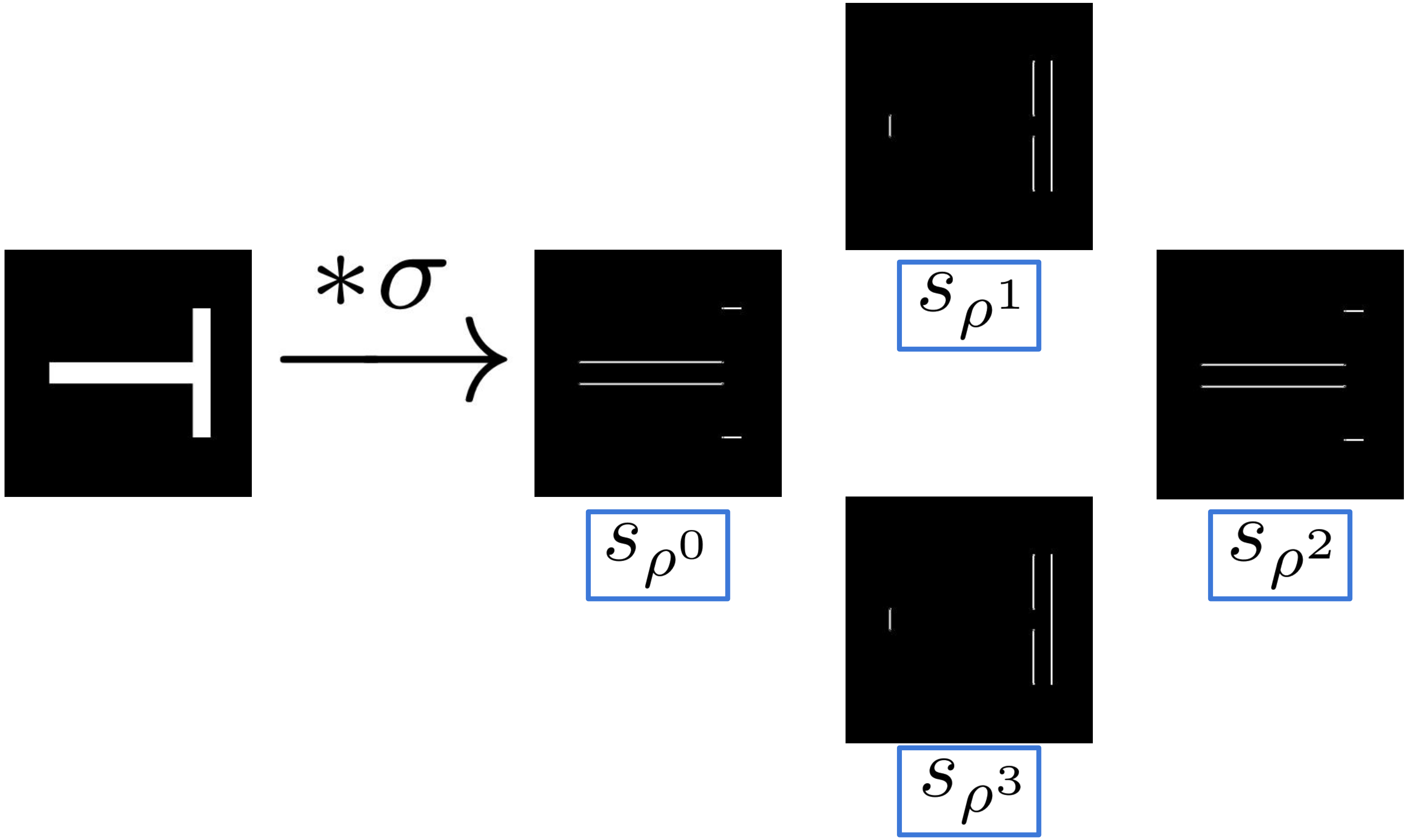

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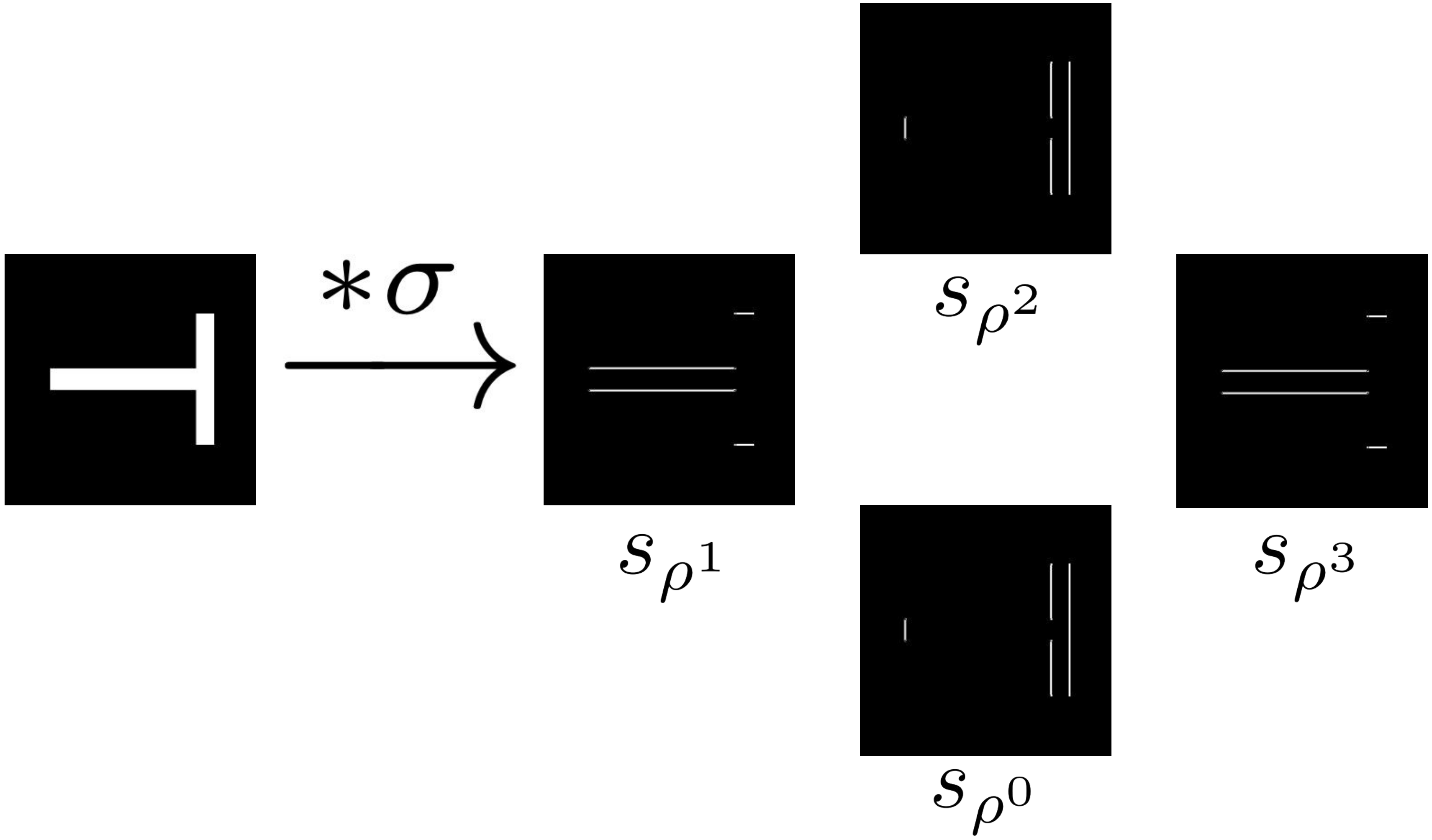

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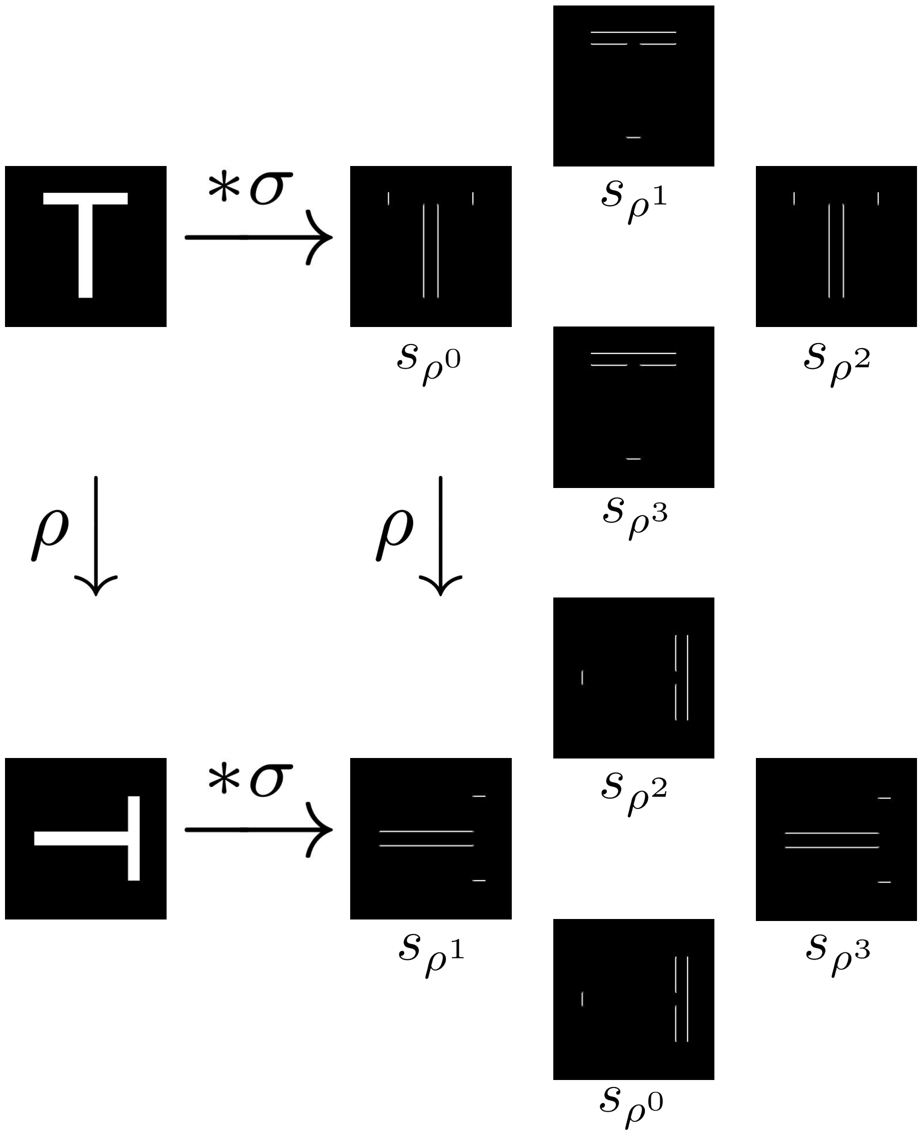

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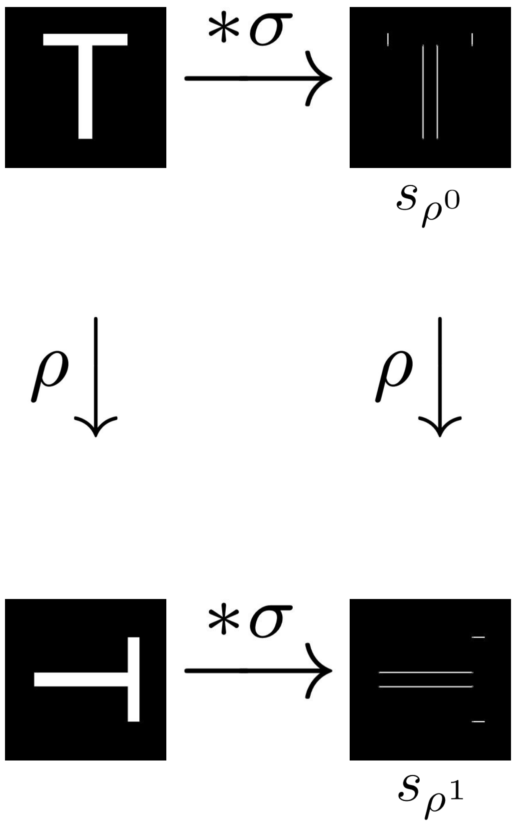
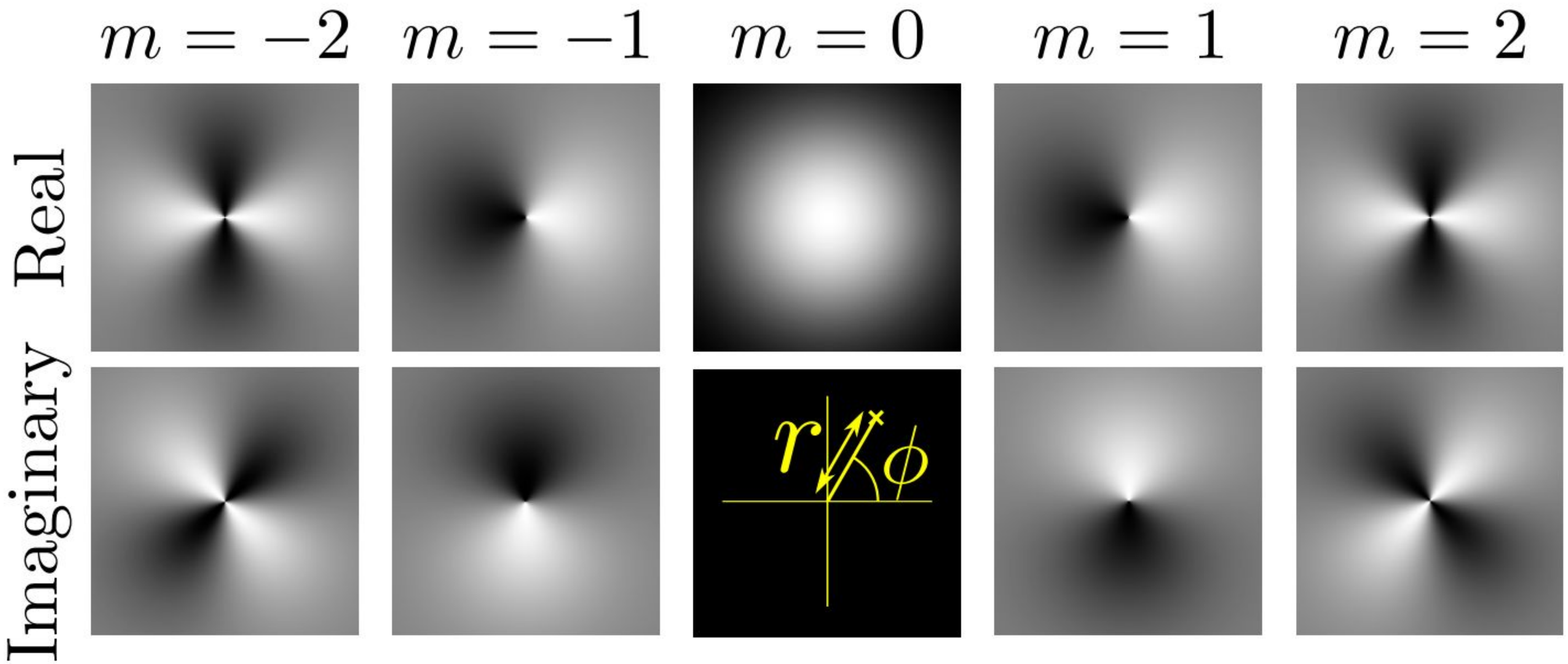


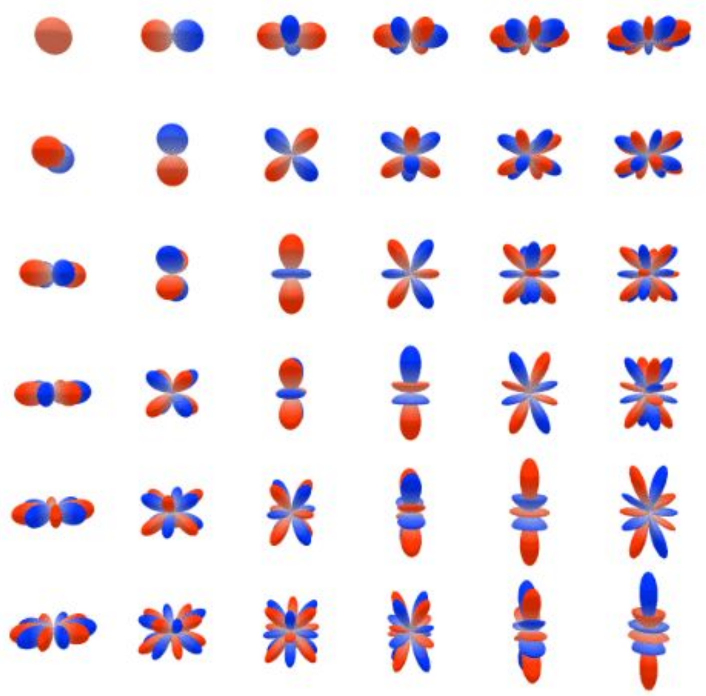
Convolution with a 2D harmonic filter



$$\mathbf{W}_m(r,\phi';e^{-r^2},0) = e^{-r^2} e^{im\phi}$$

Source: https://arxiv.org/abs/1806.03962

Convolution with a 3D harmonic filter



$$f(\rho, \theta, \phi) = \sum_{n=0}^{N} h_n(\rho) \sum_{m=-n}^{n} C_n[m] Y_{n,m}(\theta, \phi),$$

Sources: https://github.com/e3nn/e3nn, https://doi.org/10.1016/j.media.2020.101756

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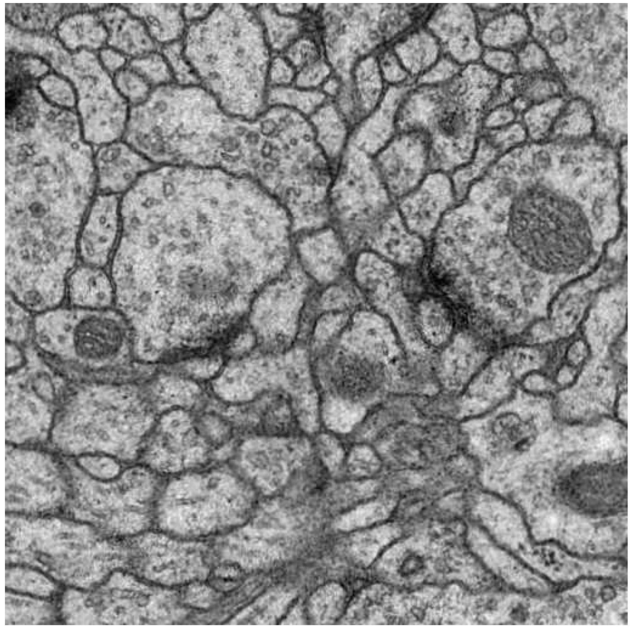

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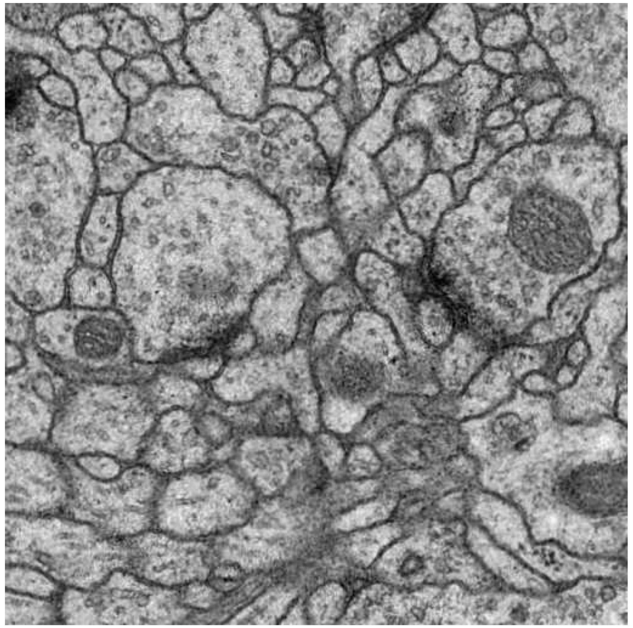

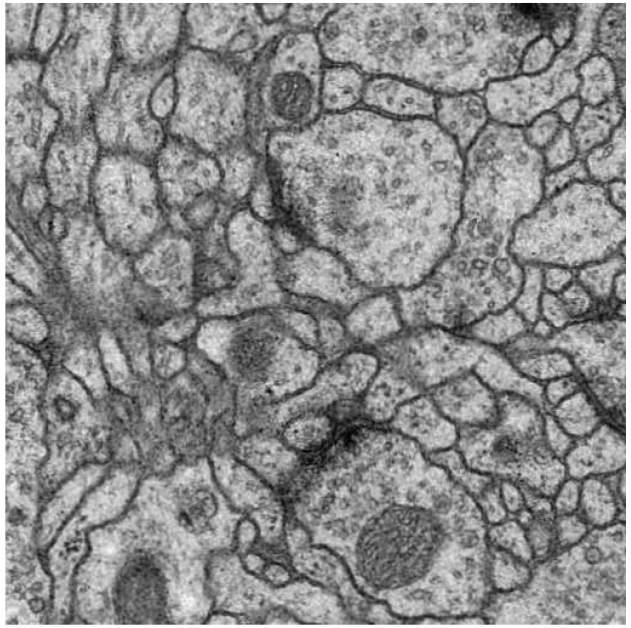

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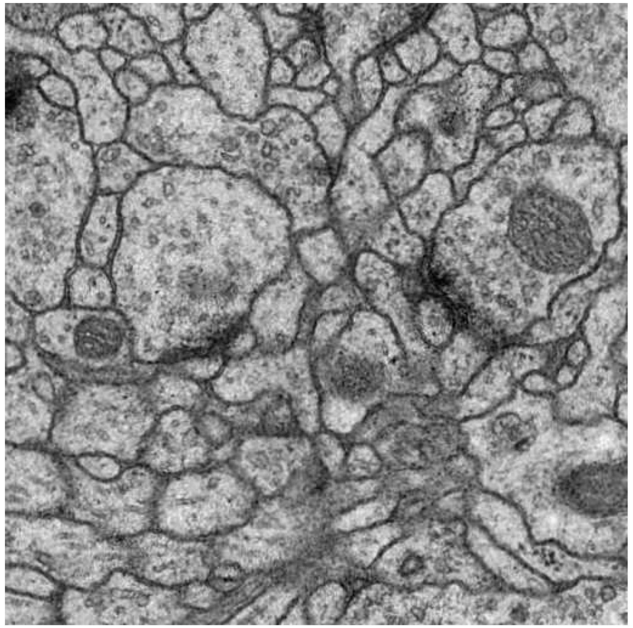

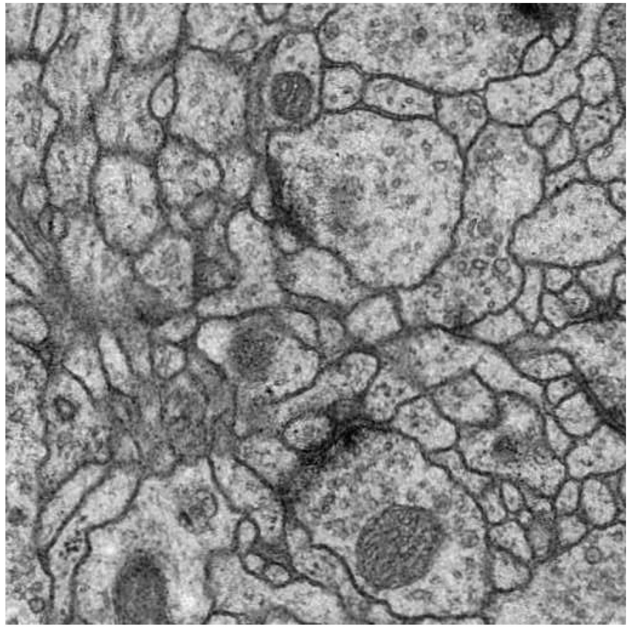

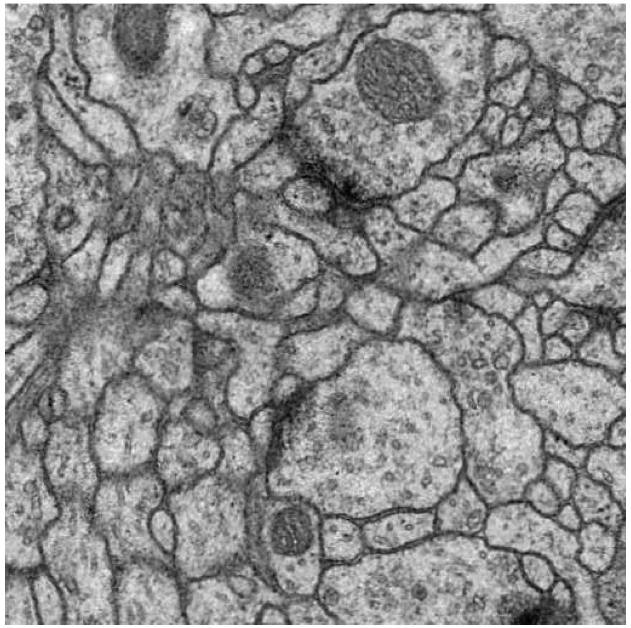

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Recent work

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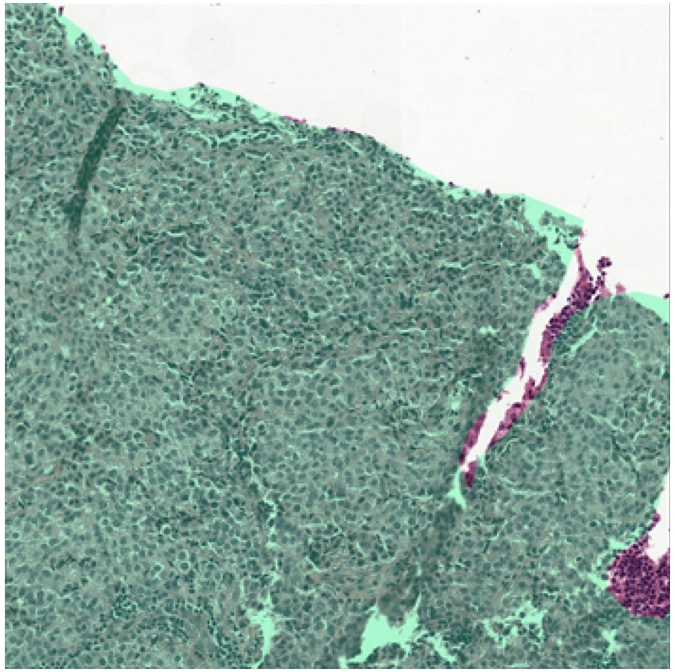
  - 2D G-CNN for tumor segmentation



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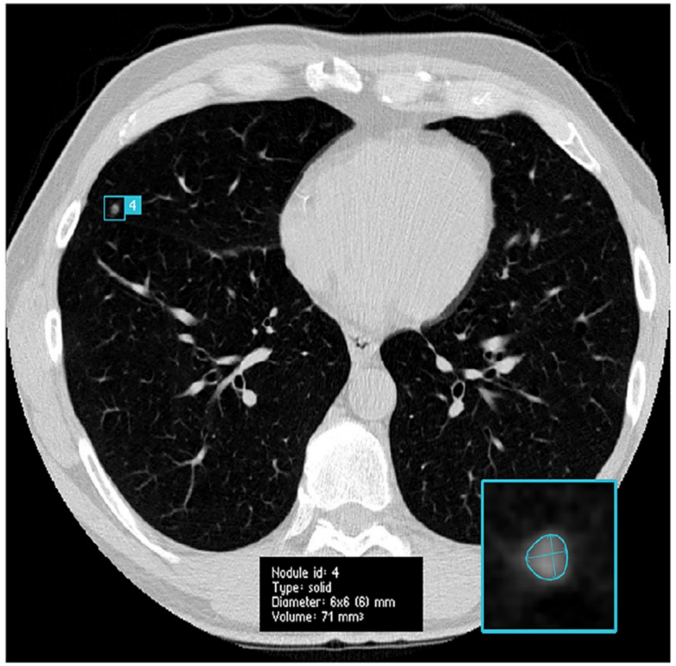

Source: https://pubmed.ncbi.nlm.nih.gov/31003034/

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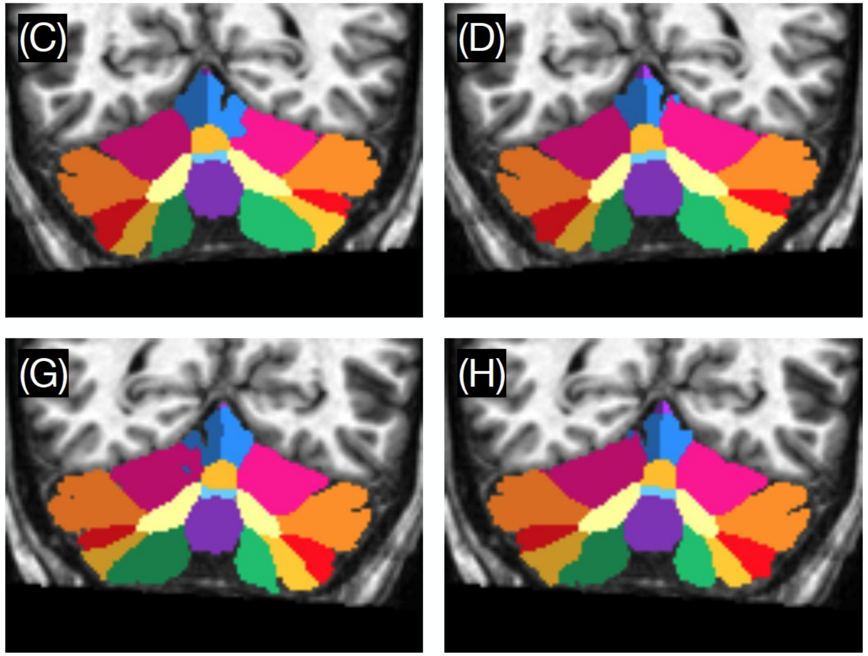

Source: https://doi.org/10.1117/12.2549399

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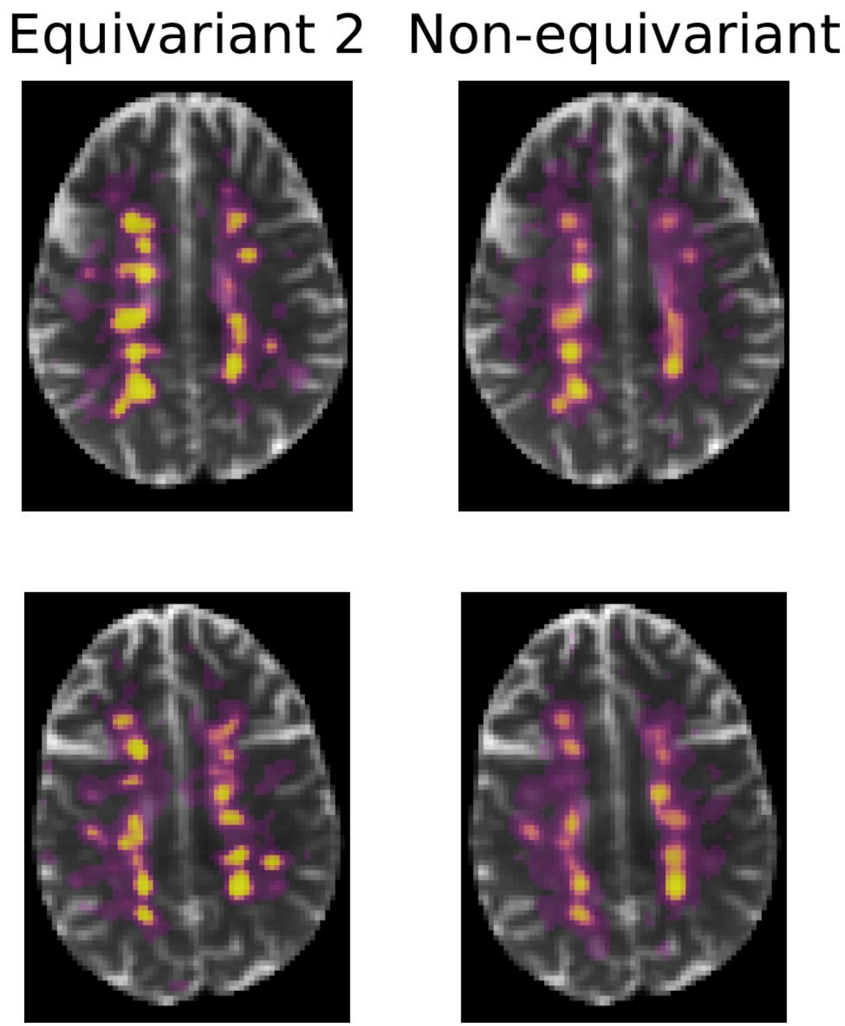
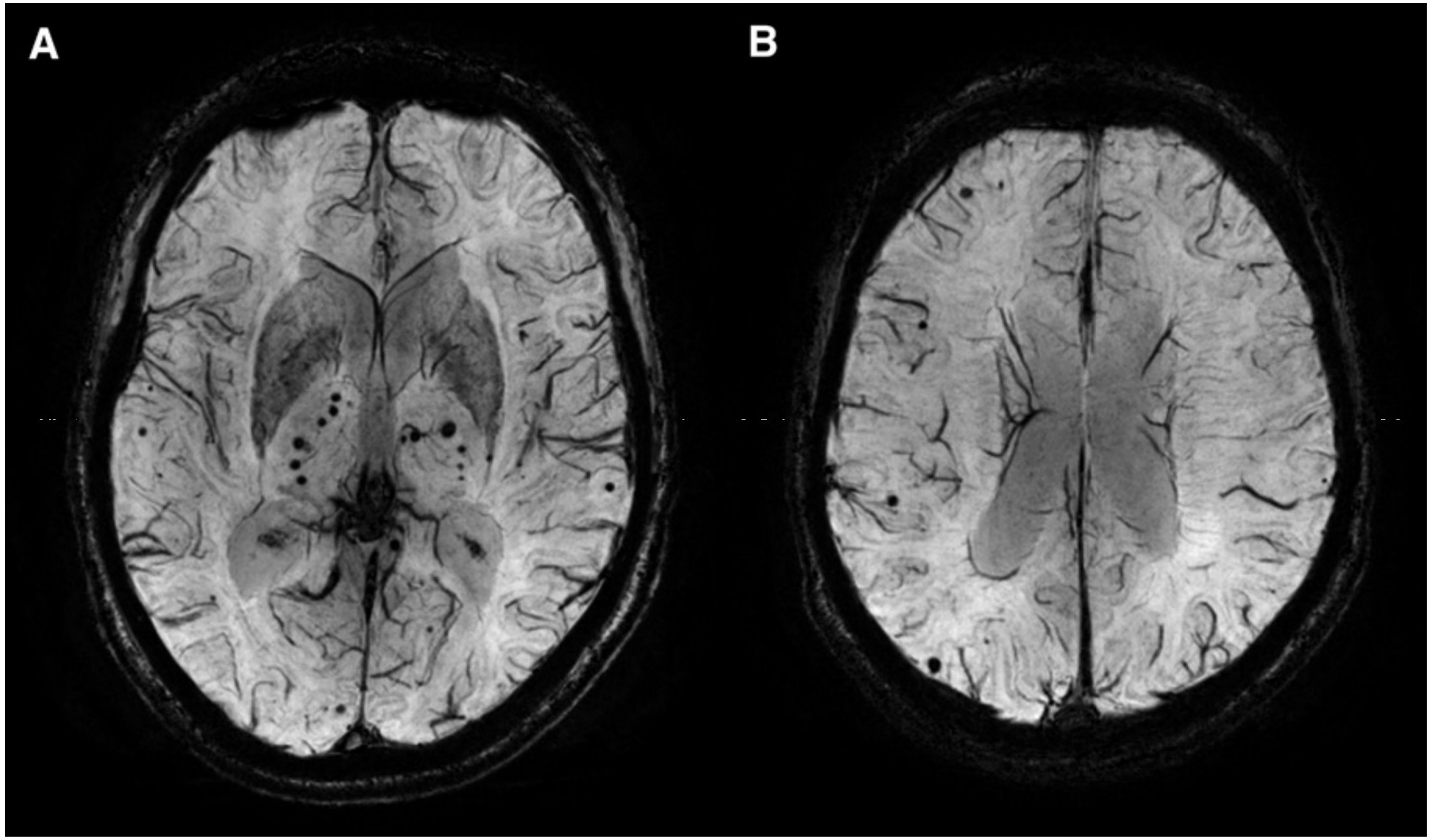
- Müller et al., 2021 (pre-print)
  - 6D G-CNN for multiple sclerosis lesion segmentation



Source: https://arxiv.org/abs/2102.06942

Application: cerebral microbleed quantification



Source: Haller et al. - Cerebral Microbleeds: Imaging and Clinical Significance

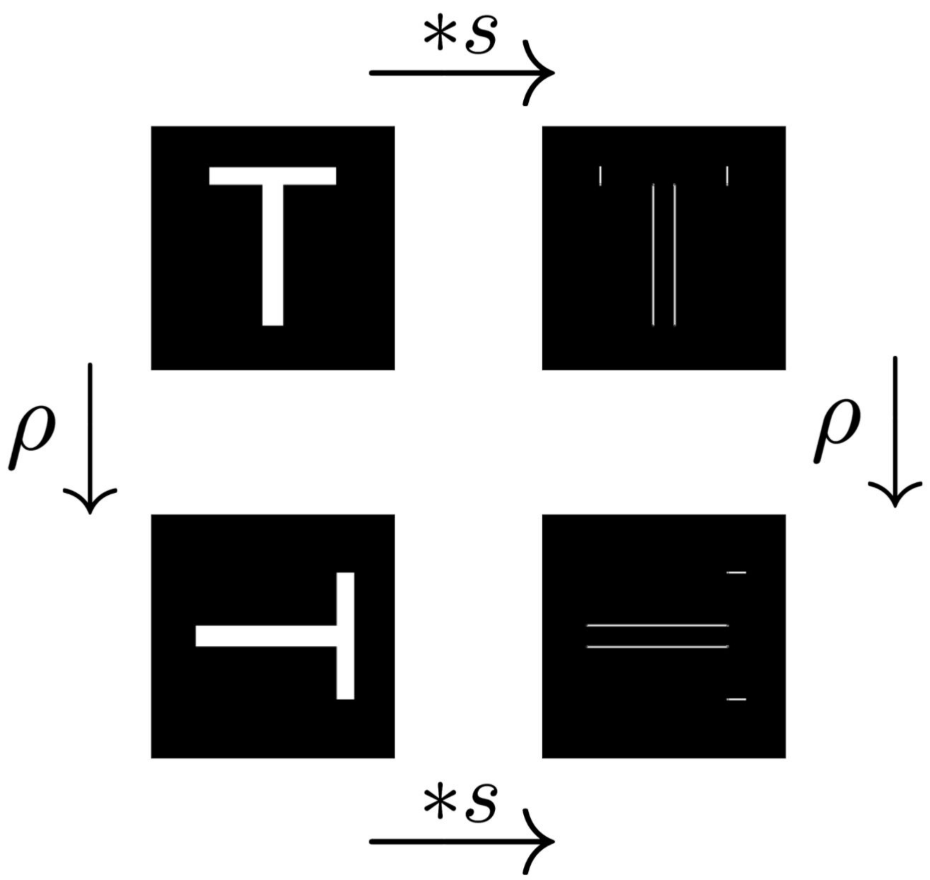
How do equivariant networks interact with brain MRIs?

Hypotheses:

- Higher sample efficiency
- Better segmentation performance
- Fewer false positives

Challenges:

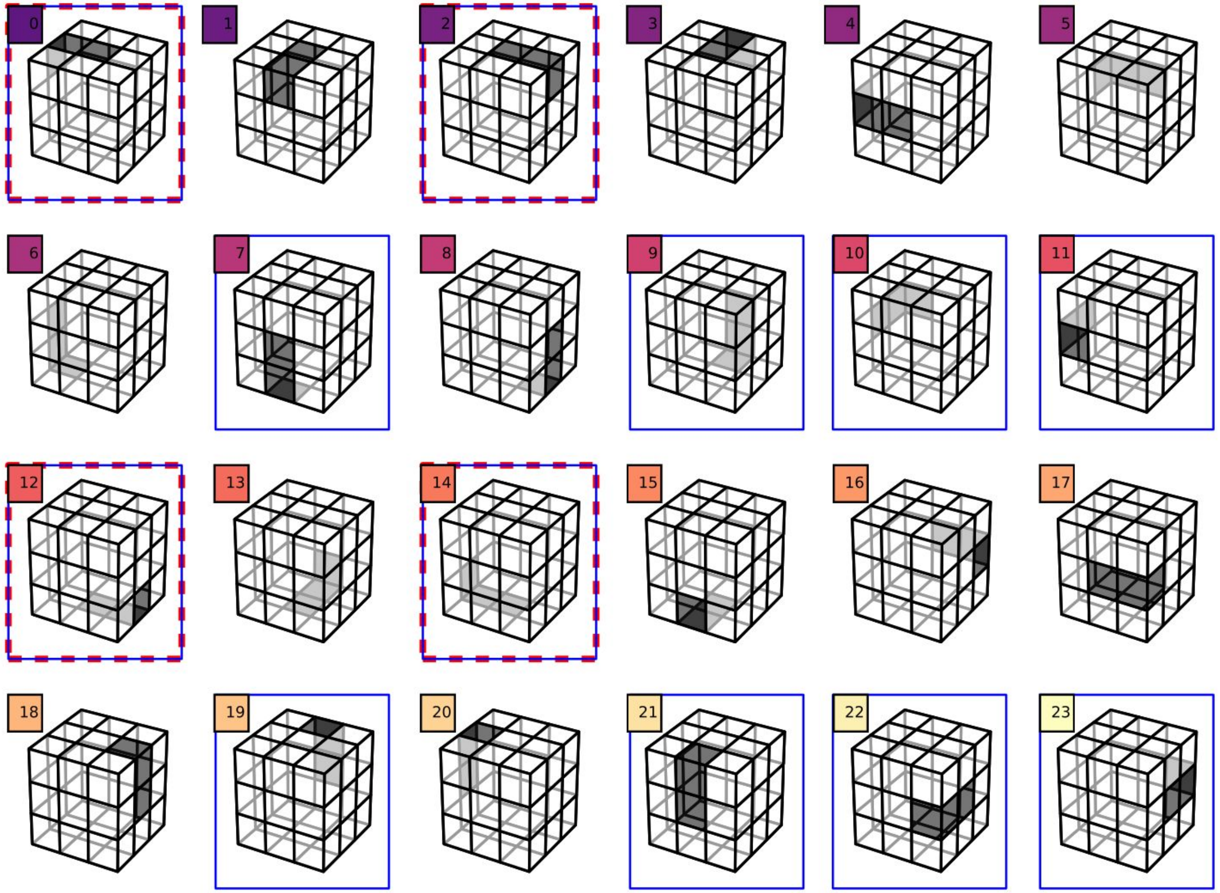
- Influence of surrounding tissue
- Non-trivial implementation



Thank you!

jami@di.ku.dk

Orbit of a filter under the octahedral group



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