HELMHOLTZ AI | ARTIFICIAL INTELLIGENCE COOPERATION UNIT

Equivariant neural networks for image segmentation

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Swiss Equivariant Learning Workshop, 12th July 2022

Goals of the project

- Deep neural networks are goto candidate for image segmentation
- Exploit symmetry in the data using group convolution operations[1]
  - Reduction in data dependency[1]
- Design & develop equivariant neural networks for image segmentation - using *e2cnn*[2] – compared to conventional network
- Investigation of synthetic and real-world datasets

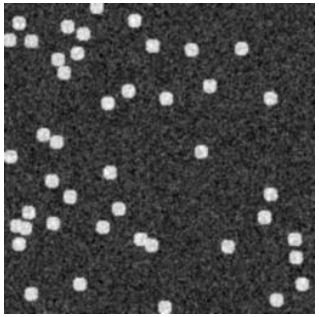
[1] Limans et.al, Sample Efficient Semantic Segmentation using Rotation Equivariant Convolutional Networks, ICML, 2020
[2] https://quva-lab.github.io/e2cnn/

Experimental design

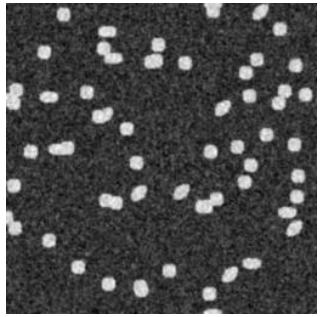
Synthetic dataset

- Gaussian based images – 500 images
- Polygonal objects having different symmetry
- Task of semantic segmentation
- Metric of choice – dice score

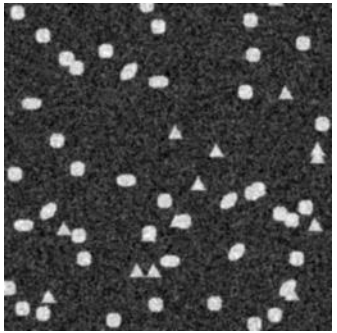
Circle



Circle + ellipse



Circle, ellipse & triangle



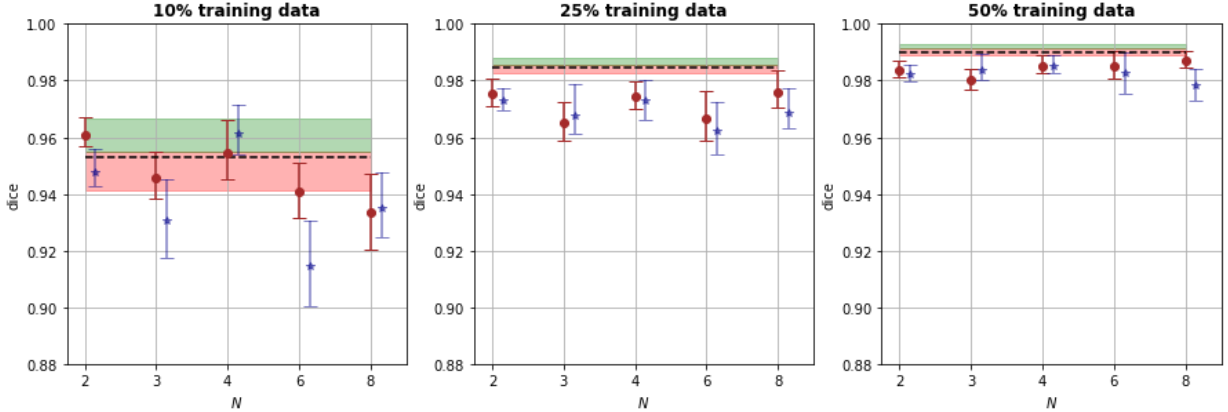
Experimental design

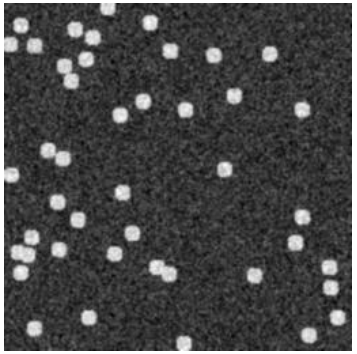
- U-net model architecture[2]
- The groups considered for the study
  - cyclic group C_N – group of (2π/N) rotations
  - dihedral groups D_N – C_N + and reflections
  - The value of N – 2,3,4,6,8
- 5-fold cross validation – uncertainty bands
- Dependency on data - 10% - 100% split for training

N	filters	Parameters (in millions)
2	40	7.45
3	39-40	7.42
4	40	8.12
6	39-40	7.85
8	40	8.01
U-net	32	7.85

Results

Circular objects

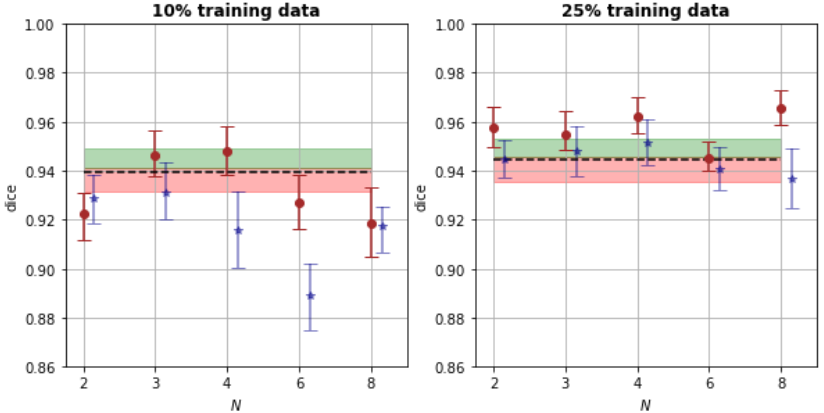


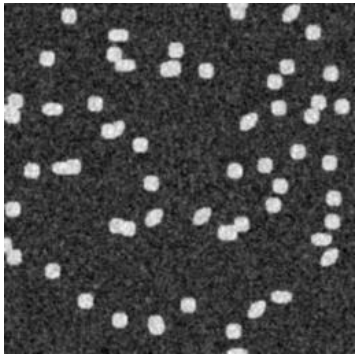


- The conv. Unet performs better for both 25% & 50% dataset
- The eq. Net scales with the U-net performance for 75% & 100% datasets

Results

Circular & ellipse objects

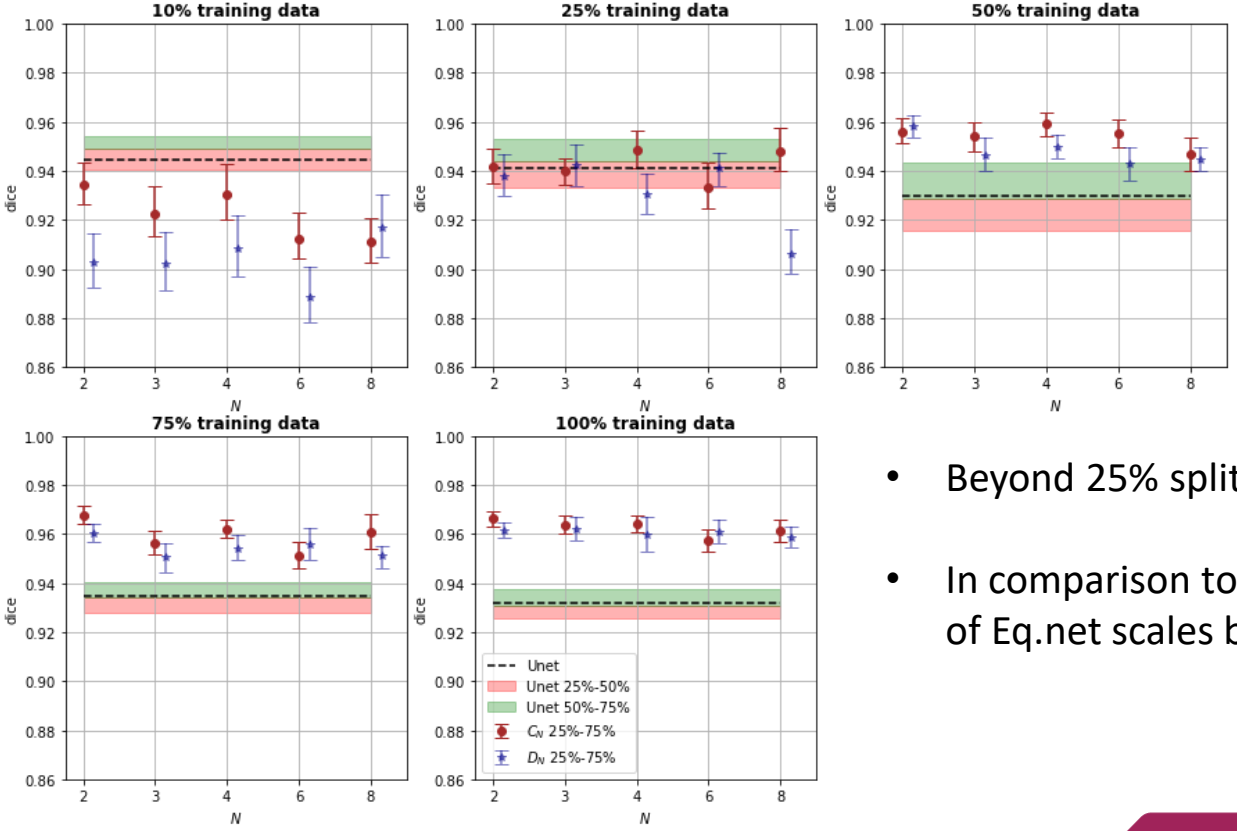


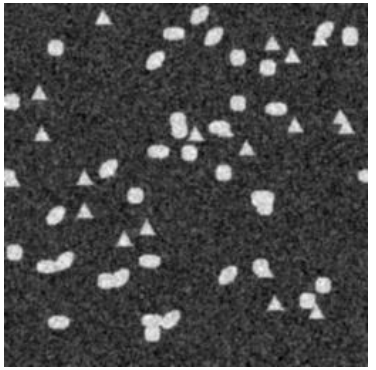


- C_2, C_3, C_4 – scale well between 10% - 50% datasets
- C_8 shows the best performance for 100% dataset
- The overall performance of the Eq.net increased in comparison to only circular objects

Results

Circular, ellipse & triangle objects

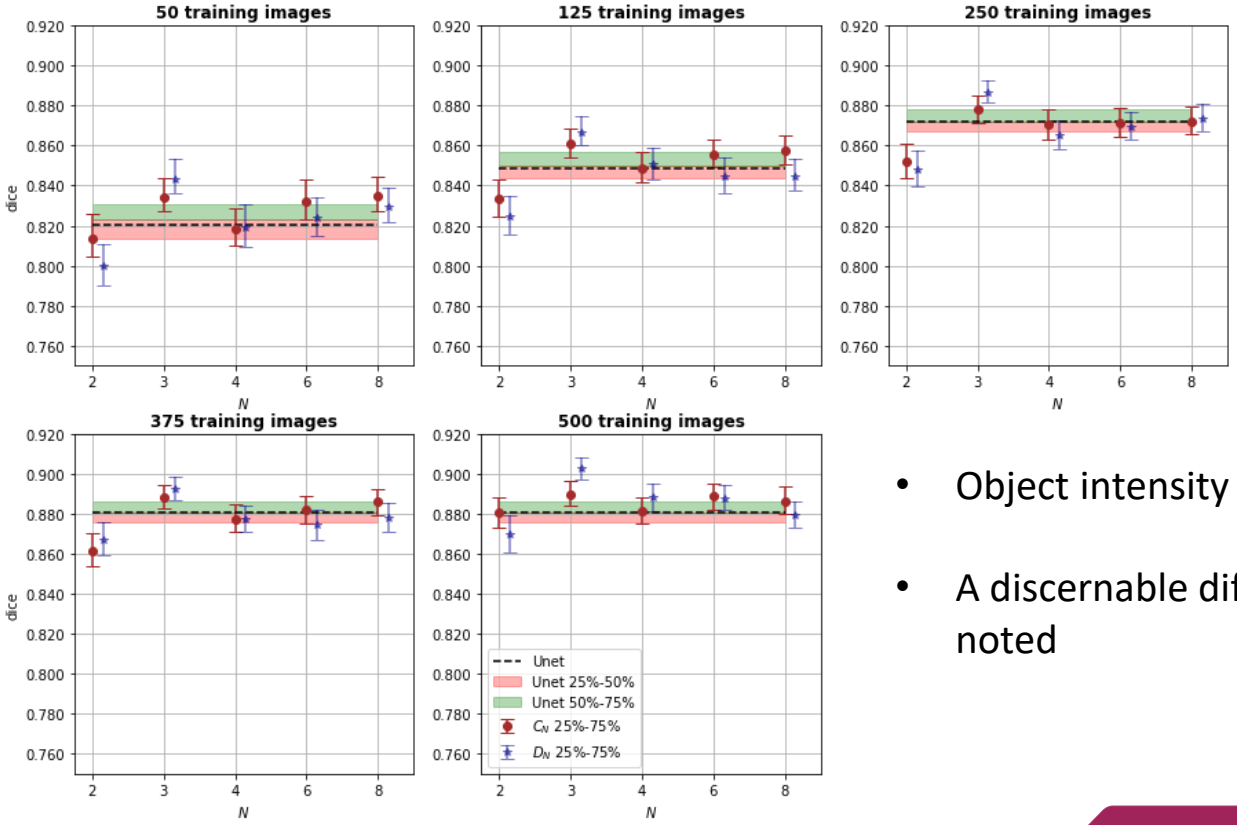




- Beyond 25% split in dataset – Eq.net dominates
- In comparison to 1 or 2 objects, the performance of Eq.net scales better than U-net

Results

Circular, ellipse & triangle objects – S/N ratio



- Object intensity at 0.5 std. of the background
- A discernable difference in performance was noted

Summary & Future outlook

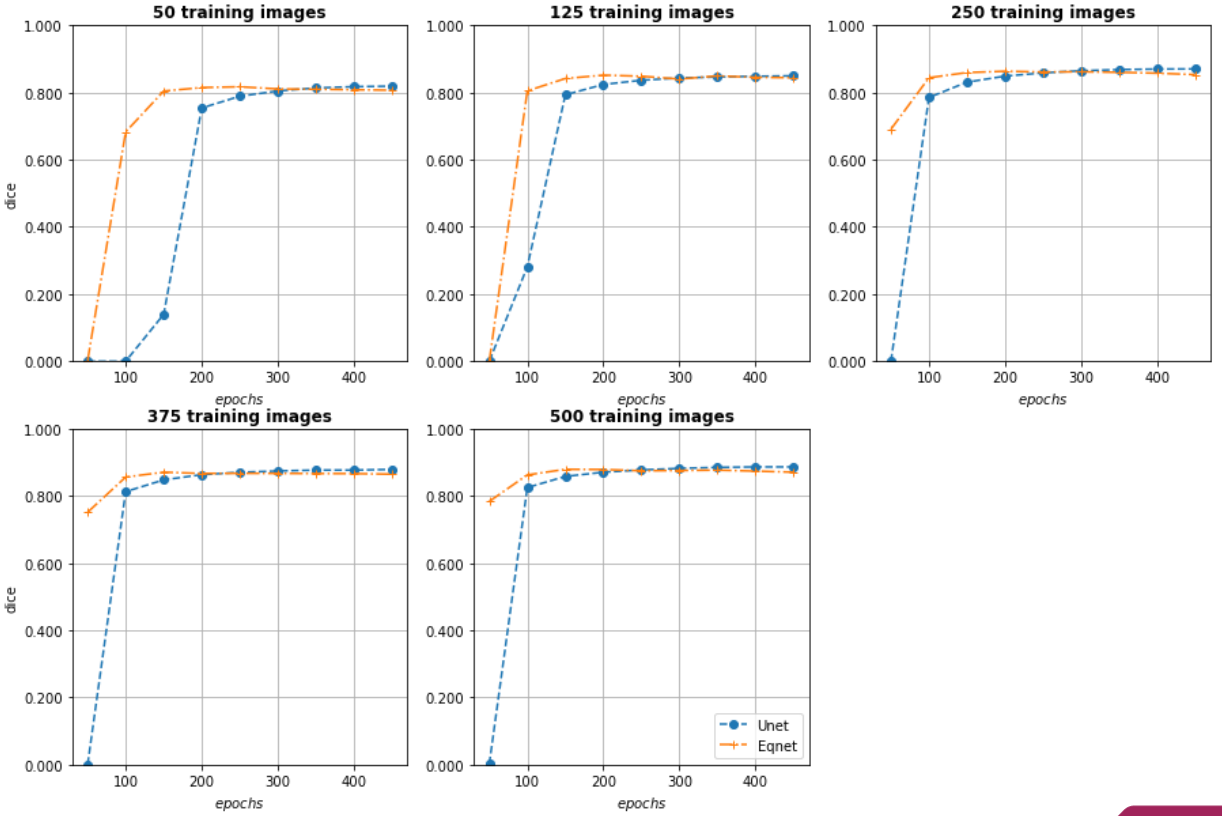
- Designed equivariant U-net for image segmentation
- Varied degree of symmetrical objects detected well by Eq.net
- Analyze the layers & study on data different scenarios

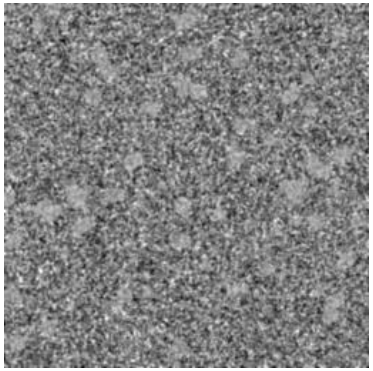
Thank You! Questions and feedback are welcome!

References

1. Taco S. Cohen, Max Welling, “Group Equivariant convolution networks”, arXiv preprint arXiv: 1602.07576, 2016.
2. Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." *International Conference on Medical image computing and computer-assisted intervention*. Springer, Cham, 2015
3. Maurice Weiler and Gabriele Cesa, ”General E(2)-Equivariant Steerable CNNs”, NeurIPS 2019.
4. Limans et.al, Sample Efficient Semantic Segmentation using Rotation Equivariant Convolutional Networks, ICML, 2020

Extra slides





Extra slides