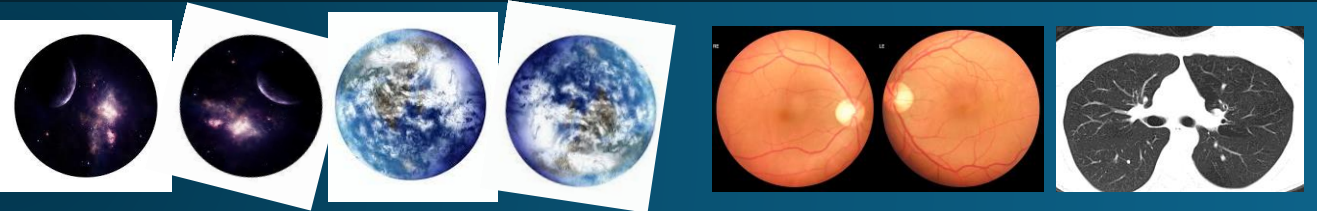


Reproducing: Learning Steerable Filters for Rotation Equivariant CNNs

Daniel Stefanov, Sohail Faizan, TU Delft



"Why care about steerable filters?"
-> Feature extraction must be orientation independent, where a global reference can not be defined

$j=0, k=0$

$j=1, k=0$

$j=2, k=0$

$j=3, k=0$

$j=0, k=1$

$j=1, k=1$

$j=2, k=1$

$j=3, k=1$

$j=0, k=2$

$j=1, k=2$

$j=2, k=2$

$j=3, k=2$

$j=0, k=3$

$j=1, k=3$

$j=2, k=3$

$j=3, k=3$

$j=0, k=4$

$j=1, k=4$

$j=2, k=4$

$j=3, k=4$

$j=0, k=5$

$j=1, k=5$

$j=2, k=5$

$j=3, k=5$

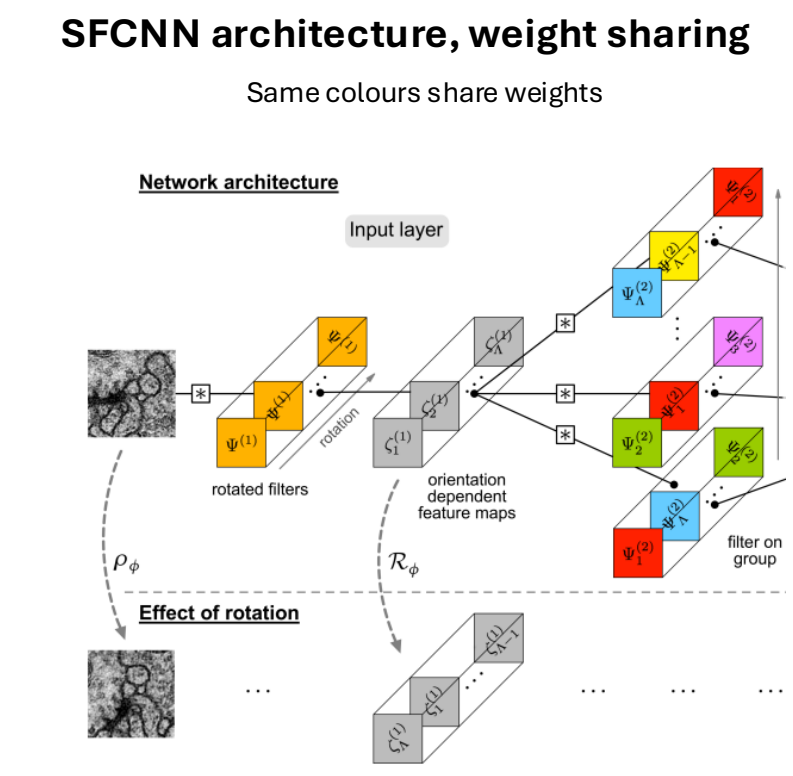
"Need for FILTERS"

$\psi_{jk}(r, \phi) = \tau_j(r) e^{ik\phi}$

(r, ϕ) denote polar coordinates

Composed filter (summation of multiple) can subsequently be steered as a whole by phase manipulation of the atoms:

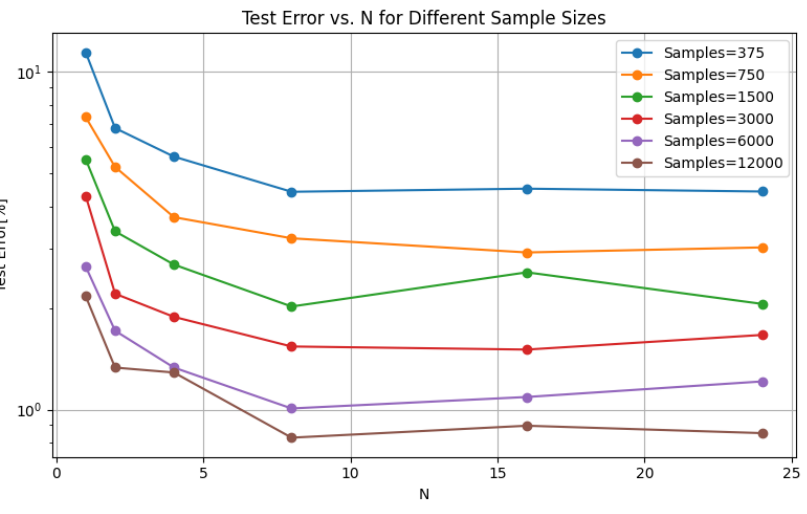
$$\rho_{\theta} \tilde{\Psi}(x) = \sum_{j=1}^J \sum_{k=0}^{K_j} w_{jk} e^{-ik\theta} \psi_{jk}(x).$$



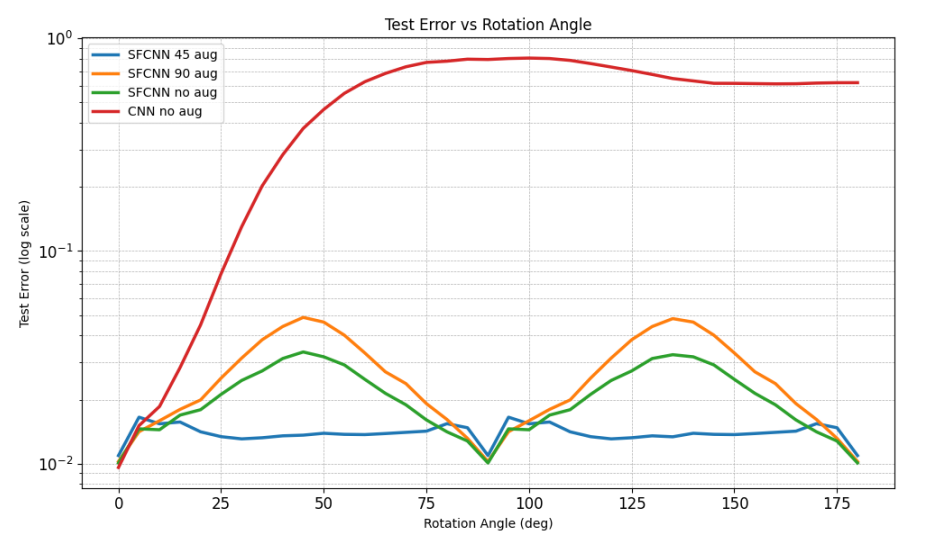
The reproduction process
(Computer: Lenovo LOQ15 NVIDIA RTX4050, CUDA 12)

Step 1: Fig. 2, Illustration of the circular harmonics:
- No plotting script present in project's *e2cnn* repository, replication done with torch and numpy following the theory. - design 2h / 0h run

Fig. 4, SFCNN Performance
Step 2: 4 Left, *SFCNN, Rotated MNIST, N* filter angles, Samples
- Reproduction using *e2cnn experiments*, *mnist_bench_single*
- Python 3.9, latest PyTorch, fixing 2 errors in the library files
- New feature: insert optionality for selecting test sample size
- Batch size of 32 instead of the original 64 due to hardware limitations.
- 8h design / 3h run



Step 3: 4 Right, SFCNN vs CNN, regular MNIST, augmentation
- Contacted authors who provided the "original code", *e2cnn*, came after the paper publication. Due to outdated PyTorch and CUDA compatibility, this version is very unstable - failed ❌
- Implemented augmentation strategy in the MNIST dataloader, so training images can be augmented n x 45/90 deg. For inference, model is tested with 0,5,10,15...180 deg. ➡
- 11h design / 40m run



ISBI Segmentation Challenge

ISBI 2012 2D EM Segmentation Challenge – benchmark in the paper - challenging to recreate.
No record of performance of design – no public proof.
Challenge server decommissioned – data and evaluation script made public.
Model's code not easily available.
Uses Neurofire, toolkit initially private to lab (now public).
Watershed segmentation and multicut used in postprocessing – not part of model obtained from authors.

Method	V _{Rand}	V _{Info}
IAL MC/LMC	0.98792	0.99183
CASIA_MIRA	0.98788	0.99072
Ours	0.98680	0.99144
Quan et al. [26]	0.98365	0.99130
Beier et al. [27]	0.98224	0.98845
Drozdzal et al. [28]	0.98058	0.98816

Controlled dataset testing

To meaningfully test whether models truly handle rotation equivariance, we use asymmetric, marked basic geometric shapes variations. These shapes are simple enough to generate and interpret, but also intentionally designed to be sensitive to rotation.