Friedrich-Alexander-Universität
Technische Fakultät

# AI-Based Reconstruction for Fast MRI
# A Systemic Review & Meta-Analysis

**Presentation**
**By**
**Anuraag Mishra**

Master Seminar
Spatio-Temporal data analysis techniques with application in medical imaging

# Agenda

Introduction

Background

ML/AI Architectures

Methodology

Key Findings & Highlights

Conclusion

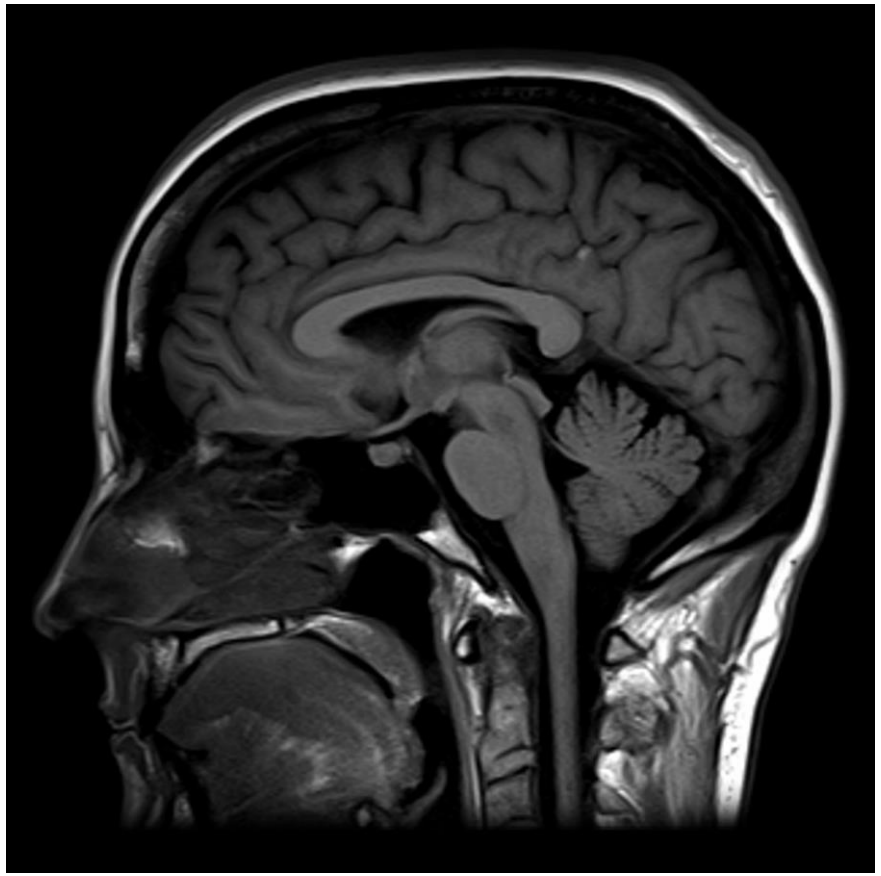
Beyond the Paper

References

QnA

# Introduction

- **Critical Role** of MRI in Medical Diagnostics
- **Challenges** of long acquisition times
- **Solution:** AI-based reconstruction as a solution
- **Goal of the paper:** Review AI advancements in MRI



*Source 8: Case courtesy of Frank Gaillard, Radiopaedia.org, rID: 2756*

# Background

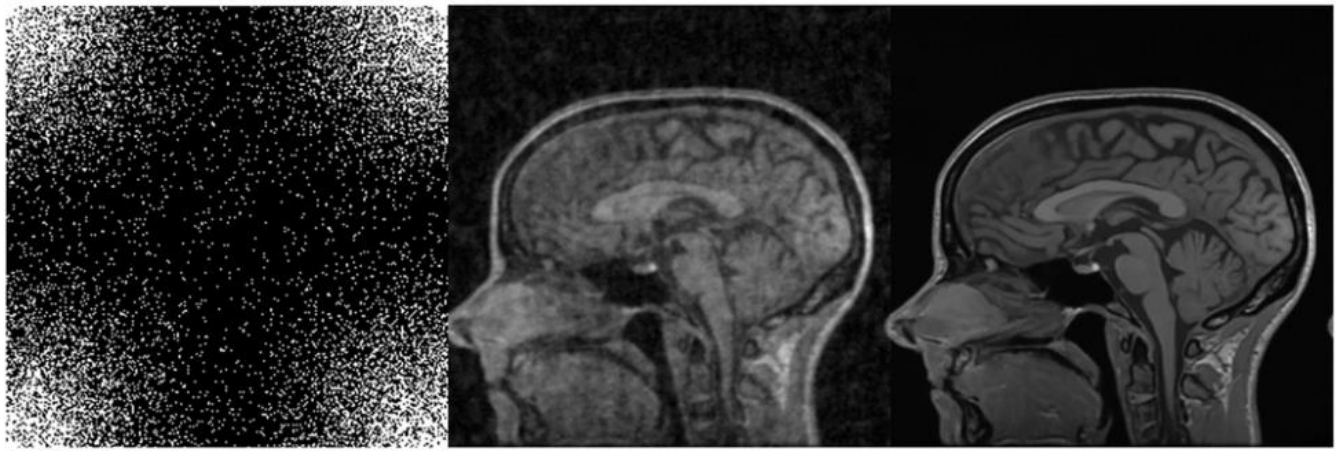
***(Left)*** *Traditional sensing samples at regular intervals.*

***(Right)*** *Compressed sensing samples at random (incoherent) intervals*

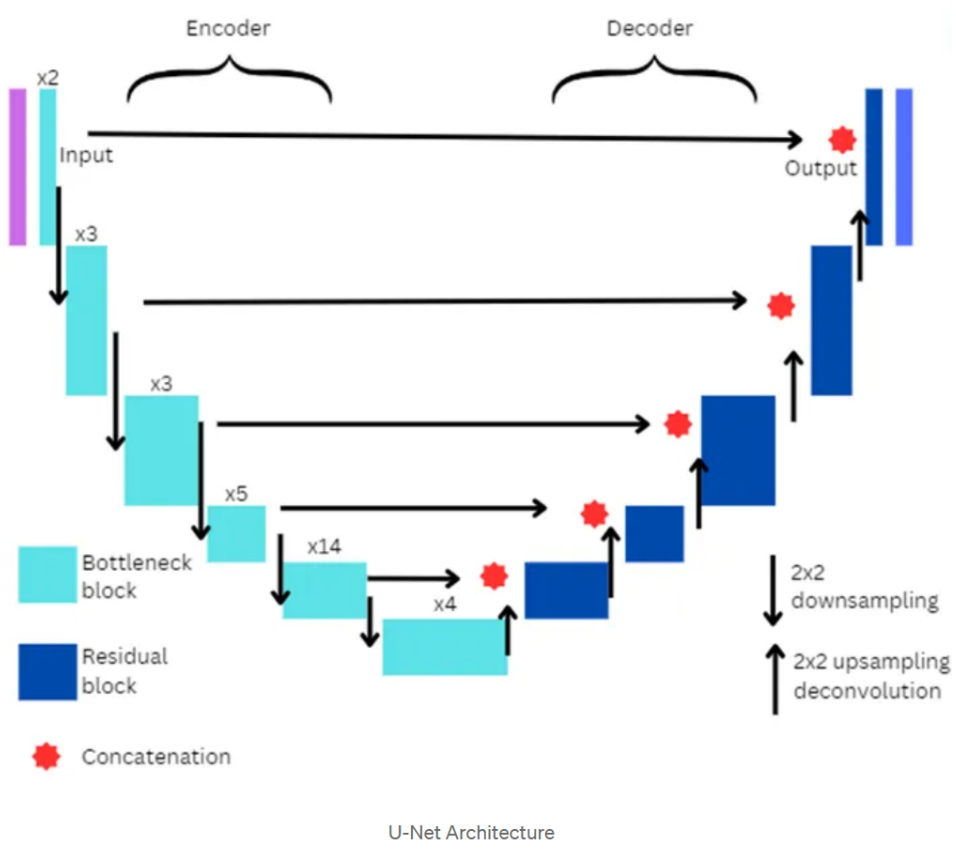

***(Left)*** *A random sampling of the original MRI space.*

***(Middle)*** *The image reconstructed without AI**.***

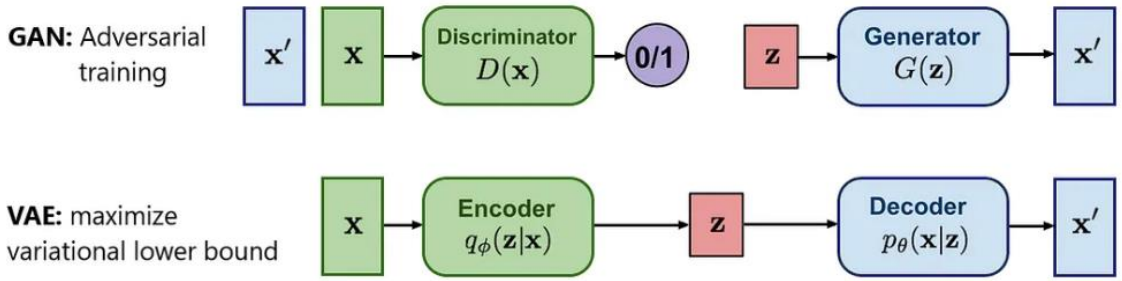
***(Right)*** *The image reconstructed with AI (combined with CS)*



# ML/AI Architectures

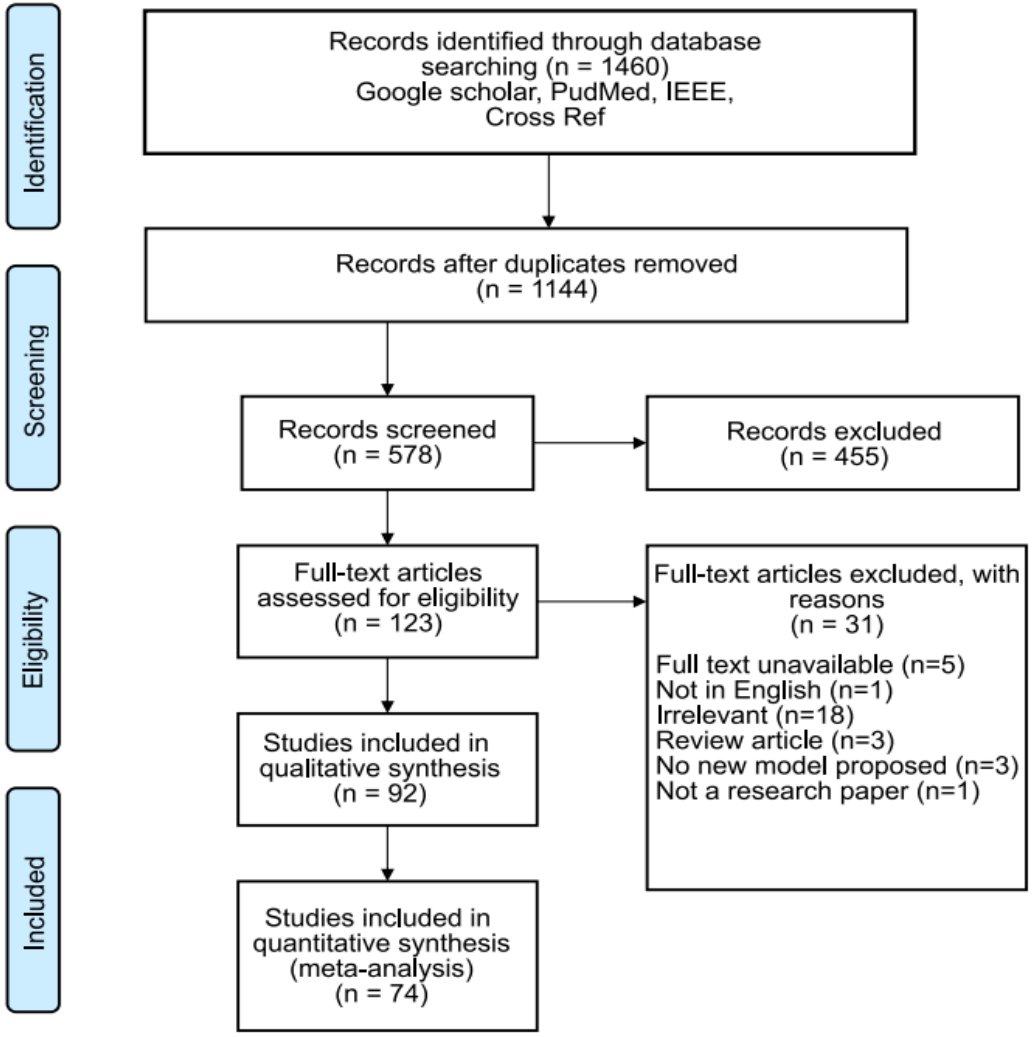


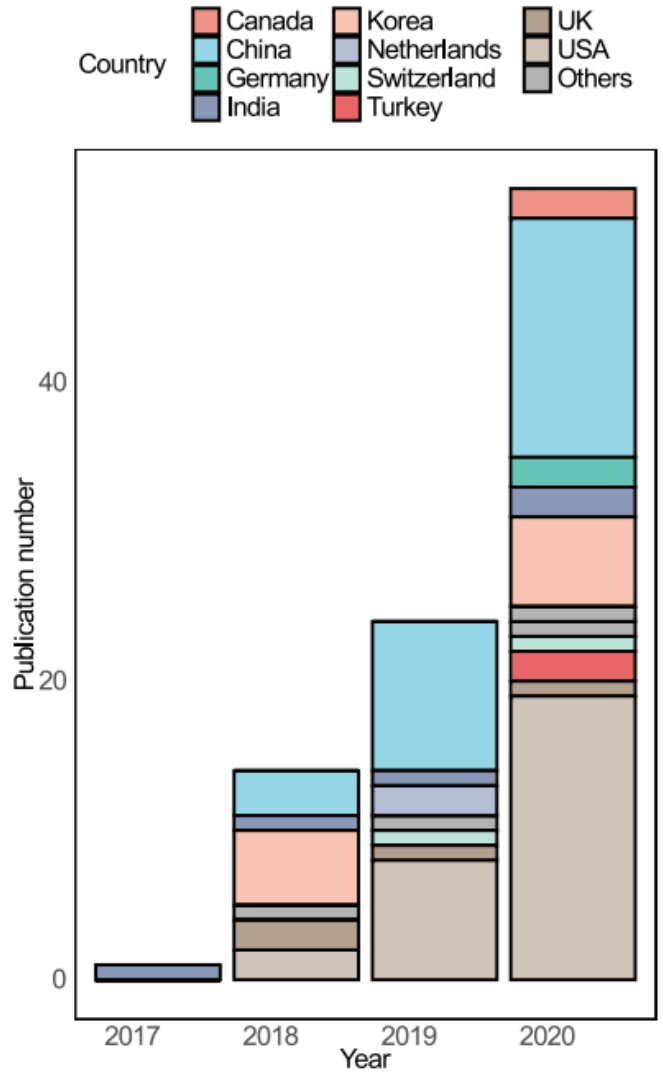

U-Net Architecture



# Methodology

## Data collection process



# Methodology

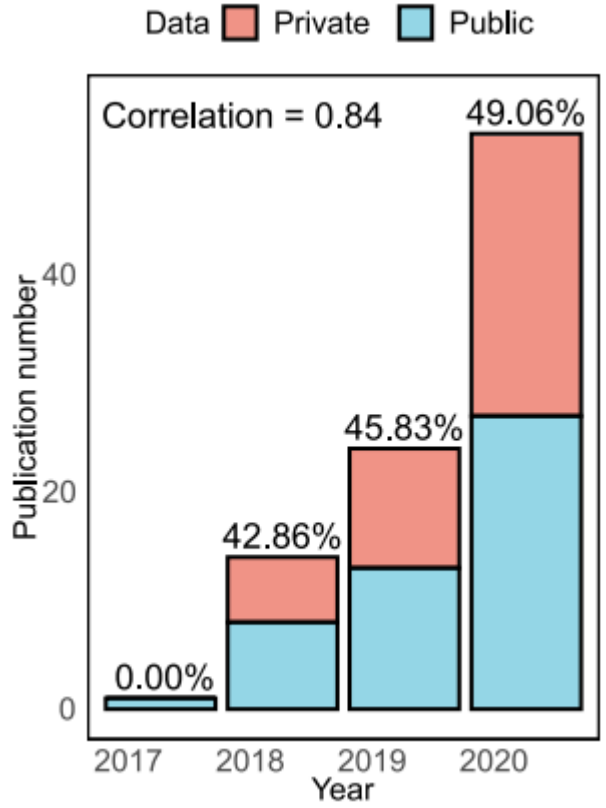
## Data Collection

- Number of studies used in each analysis test.
- Abbreviations:
  - **PCA**: principal component analysis;
  - **SSIM**: structural similarity index, a popular metric of performance of deep learning model in CS reconstruction;
  - **PSNR**: peak signal-to-noise ratio.

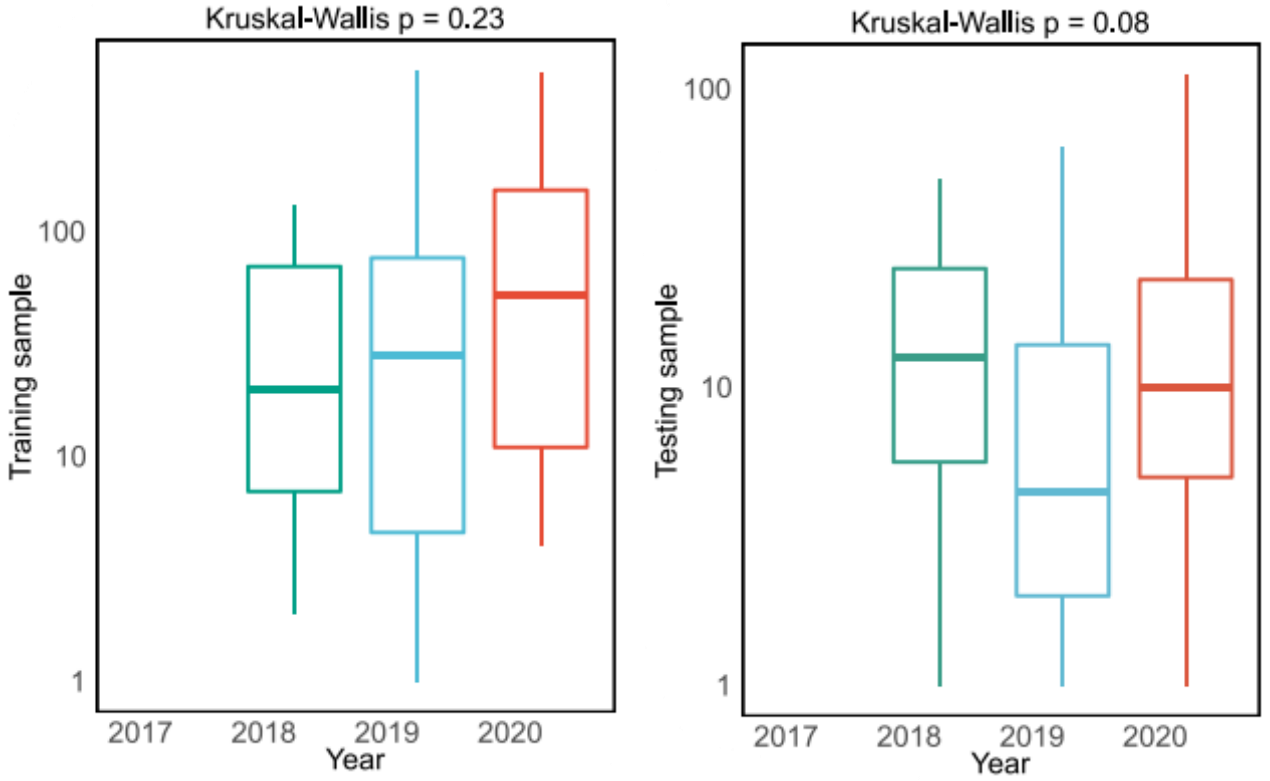
| Statistical test | Number |
|---|---|
| Frequency bar charts | 92 |
| PCA and clustering analysis | 92 |
| Comparison of SSIM performance | 52 |
| Comparison of PSNR performance | 46 |
| Deeks' test for SSIM improvement | 16 |
| Deeks' test for PSNR improvement | 9 |

# Methodology

## Dataset-type & Sample-size



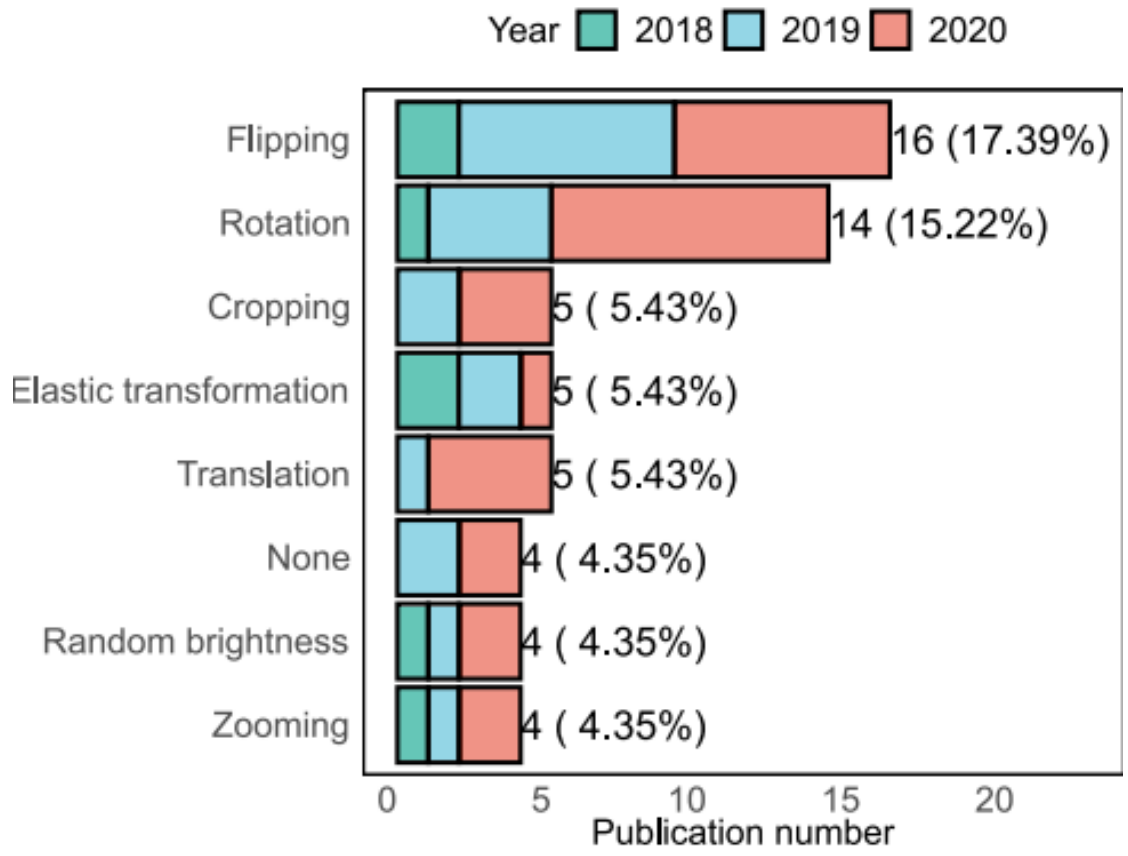

public vs private $(corr = 0.84)$ datasets

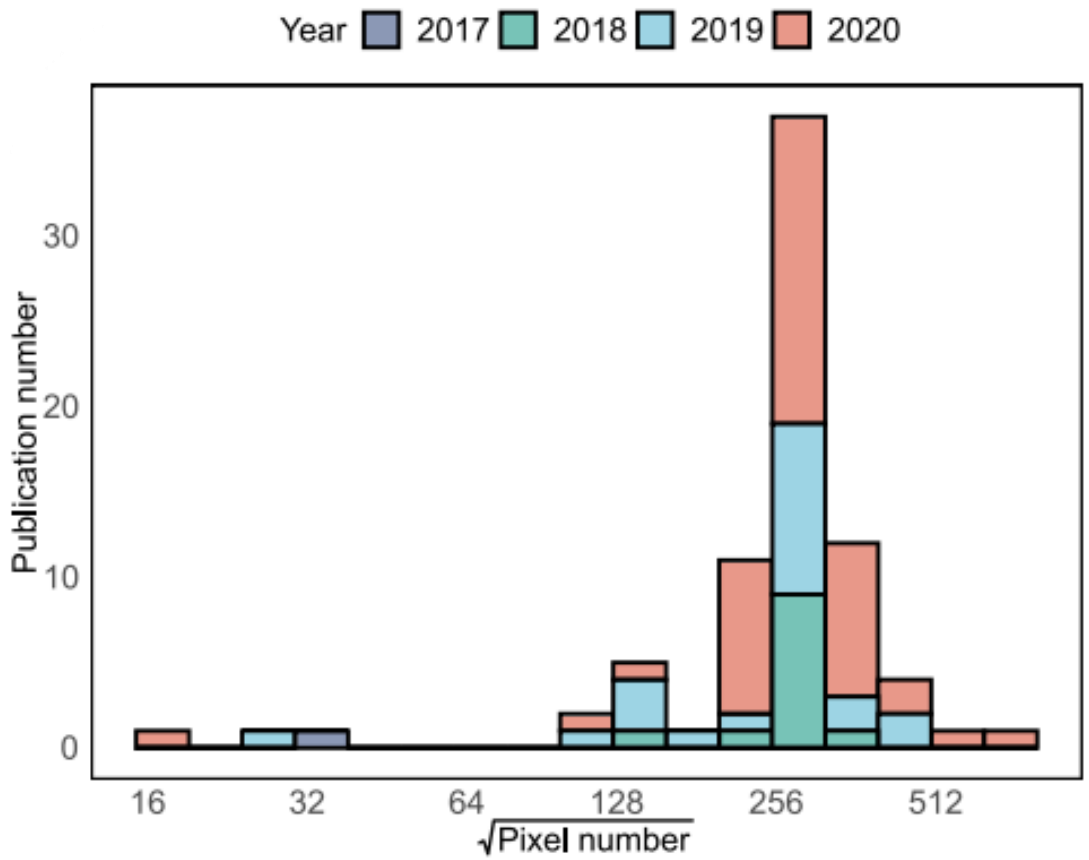



Training and Testing sample sizes over time

# Methodology

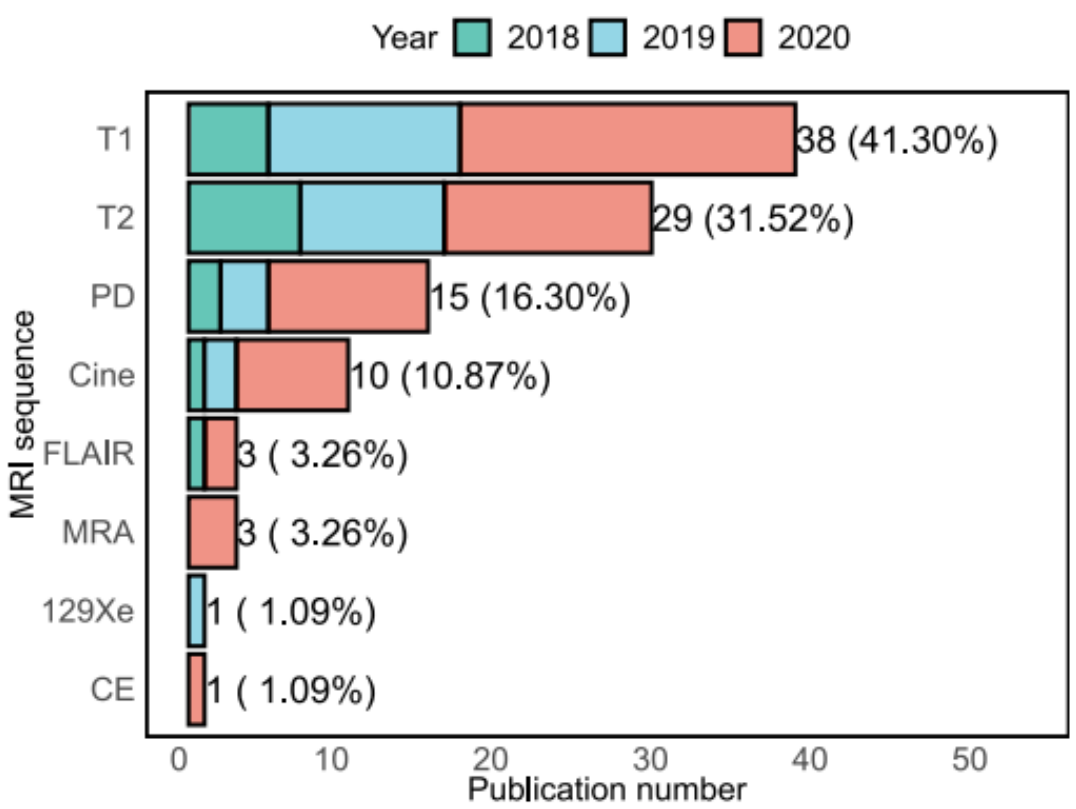
## Input data Augmentation & Input Pixel number

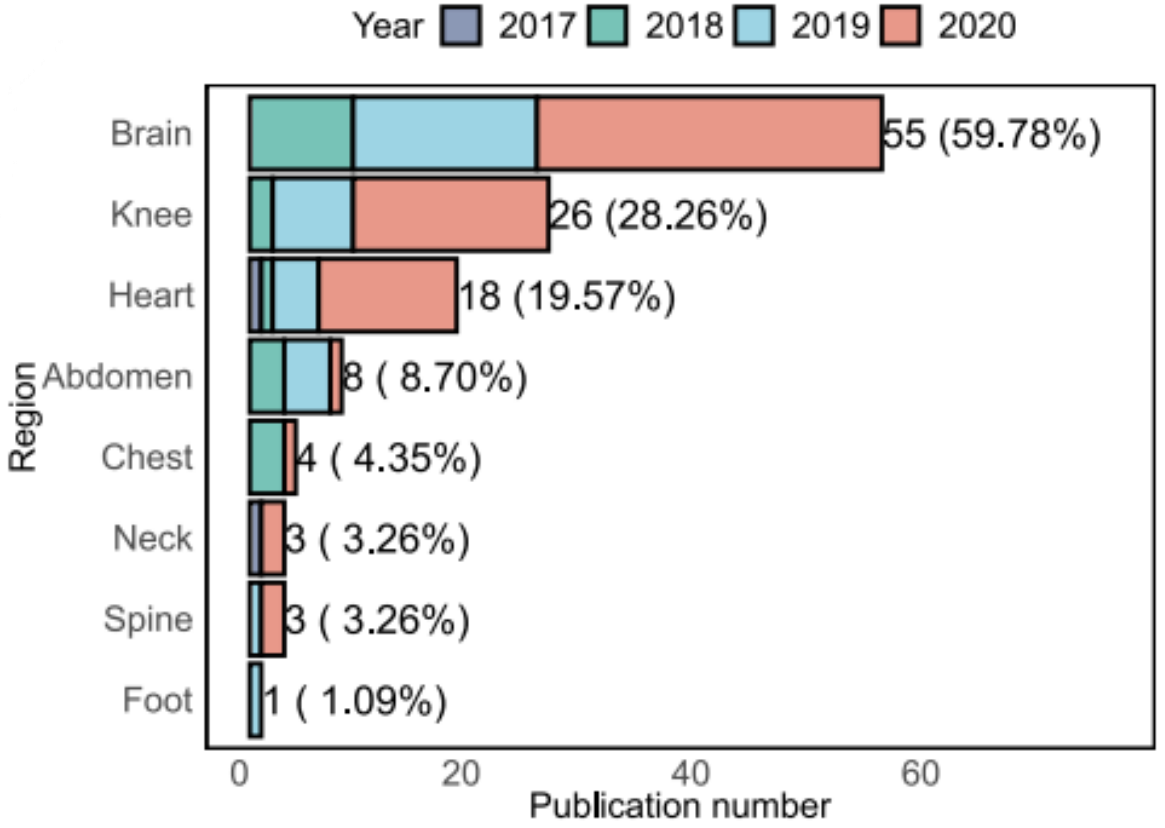


# Methodology

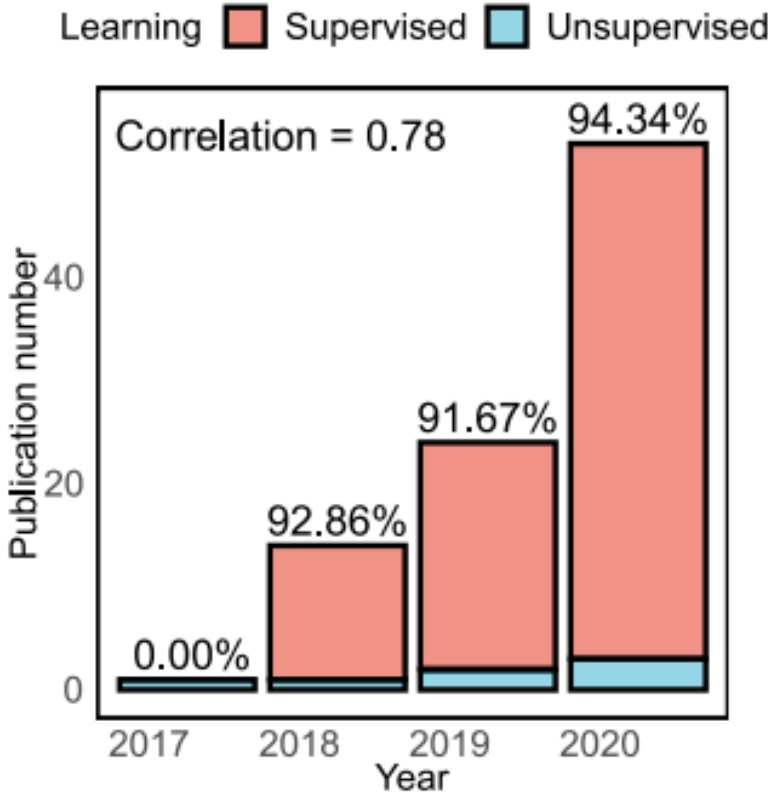
## MRI Sequence & MRI region

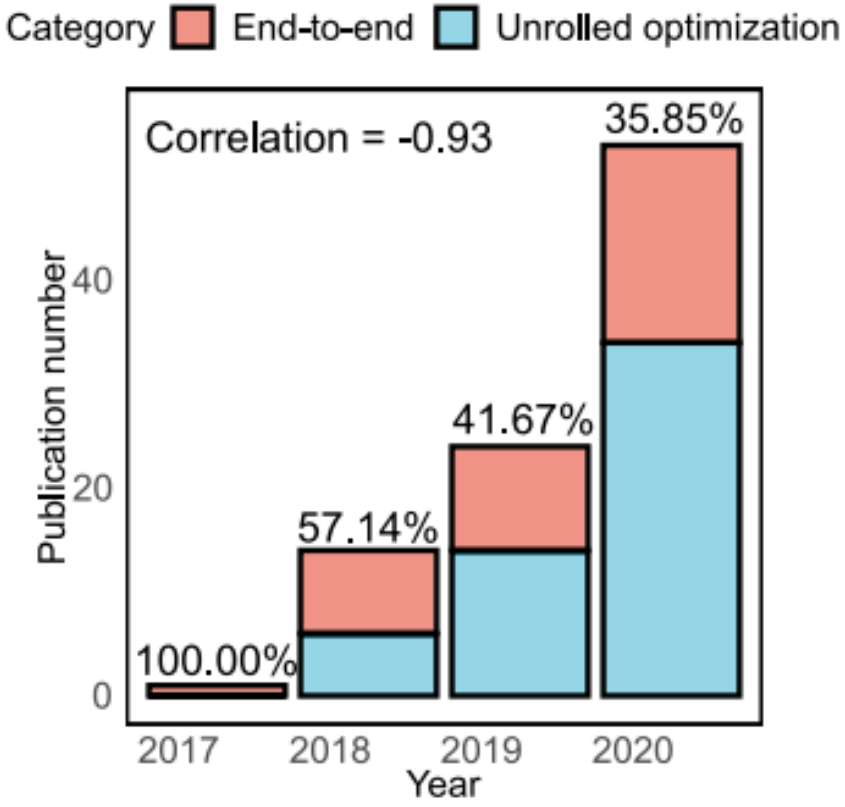


# Key Findings and Highlights

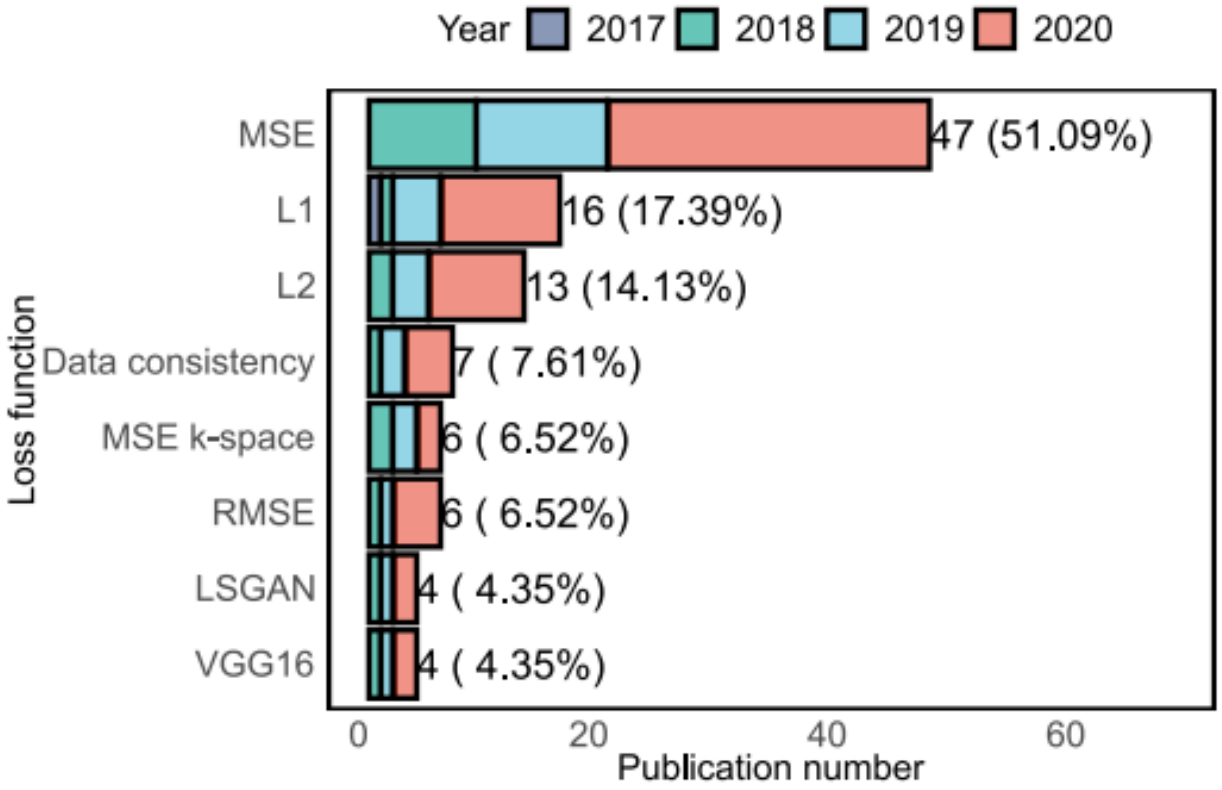
## Learning Type & Category

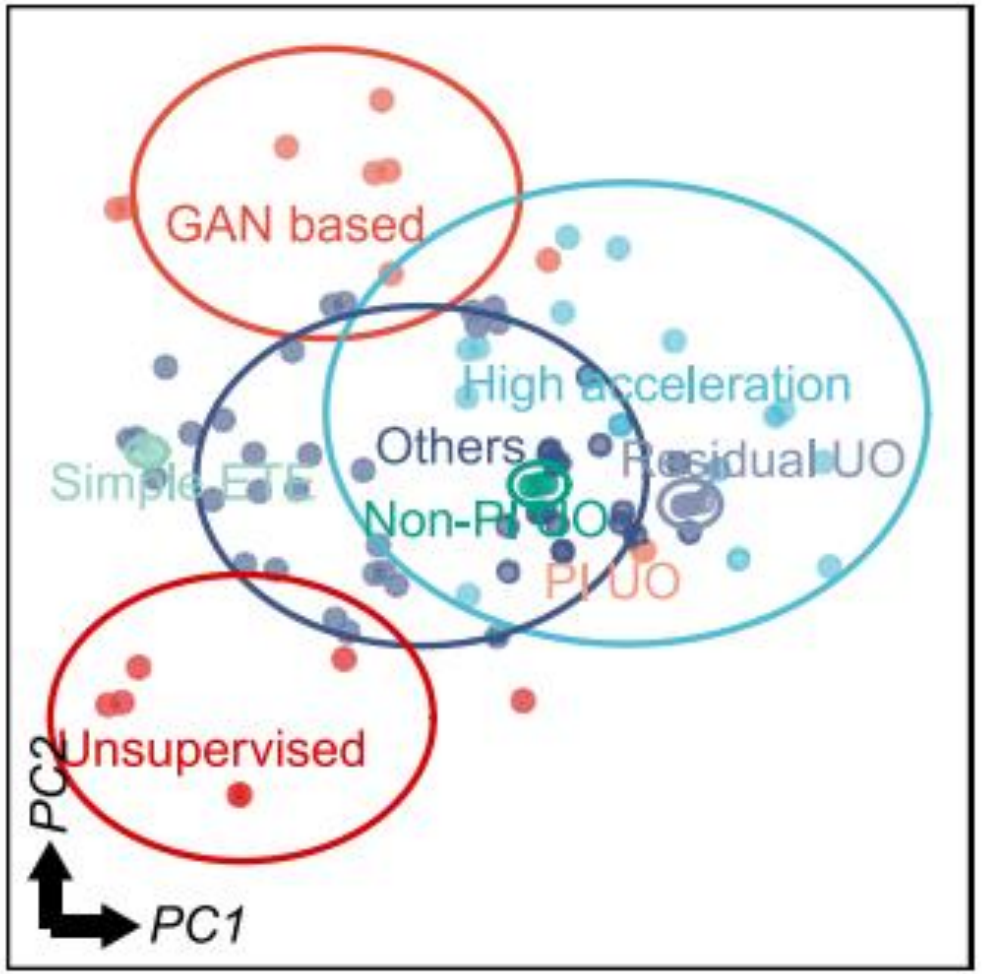


# Key Findings and Highlights

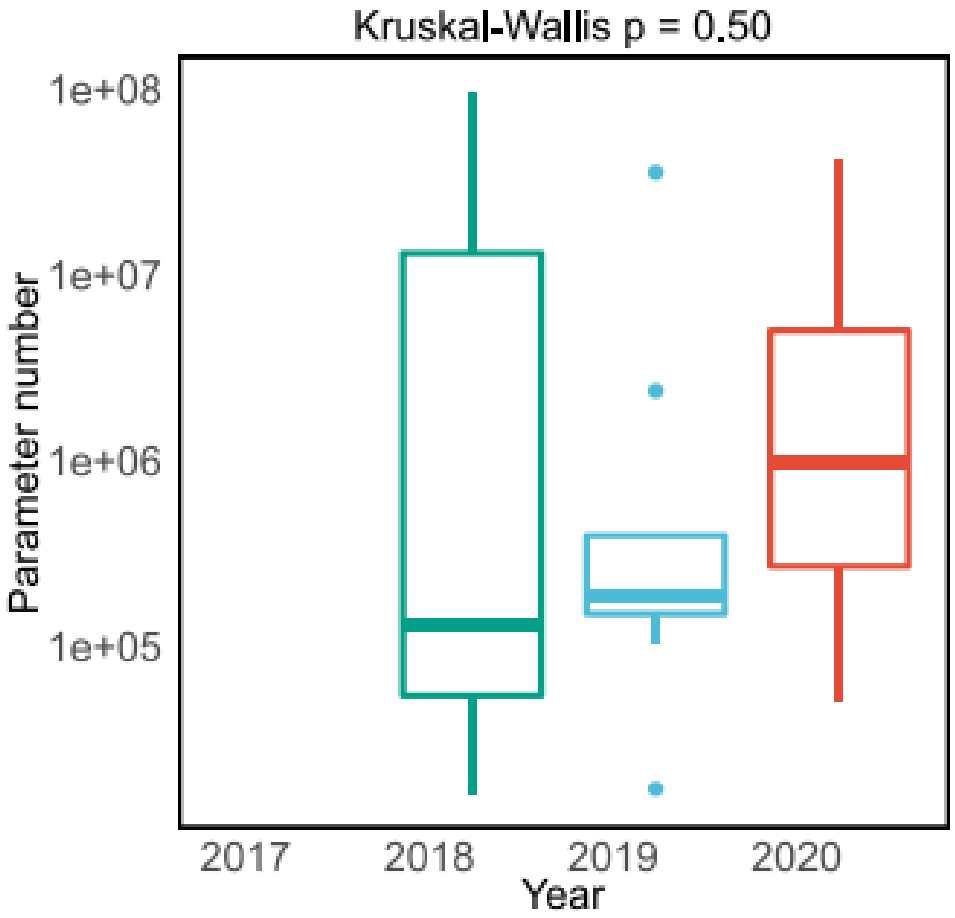
## Loss Function & Clustering

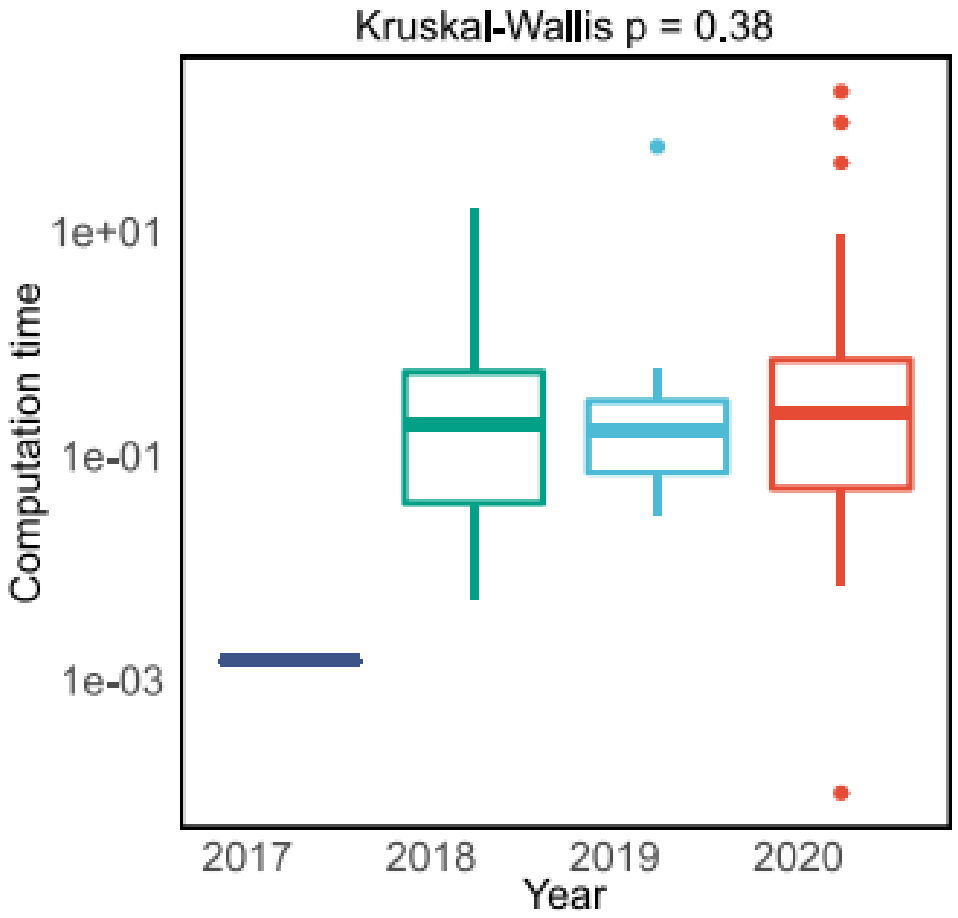


# Key Findings and Highlights

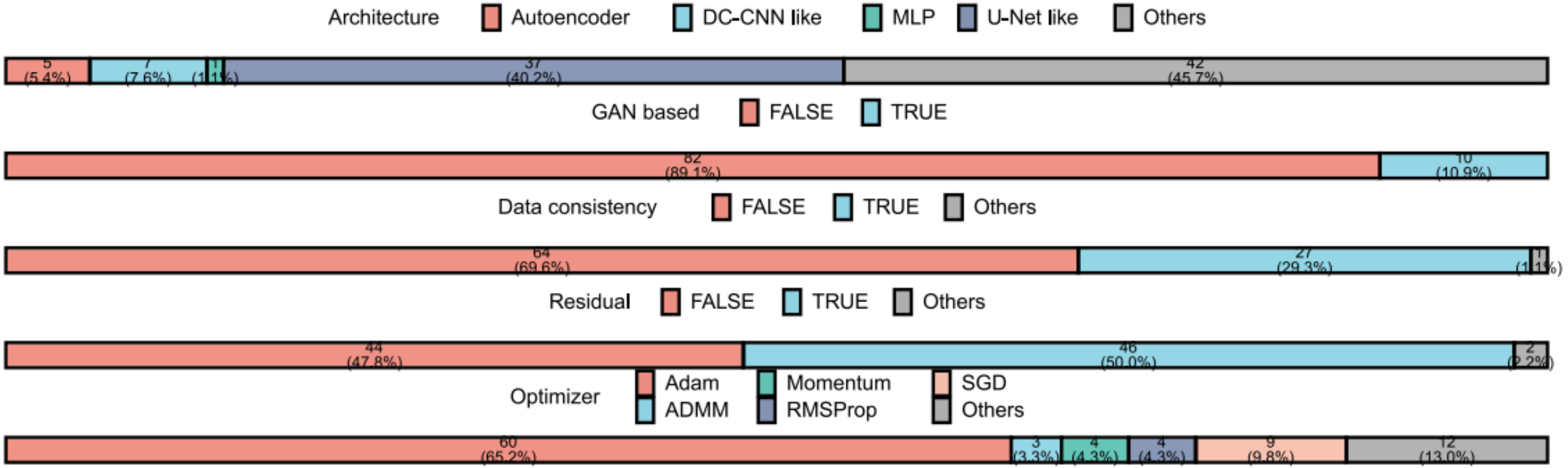
## Parameter number & Computation time



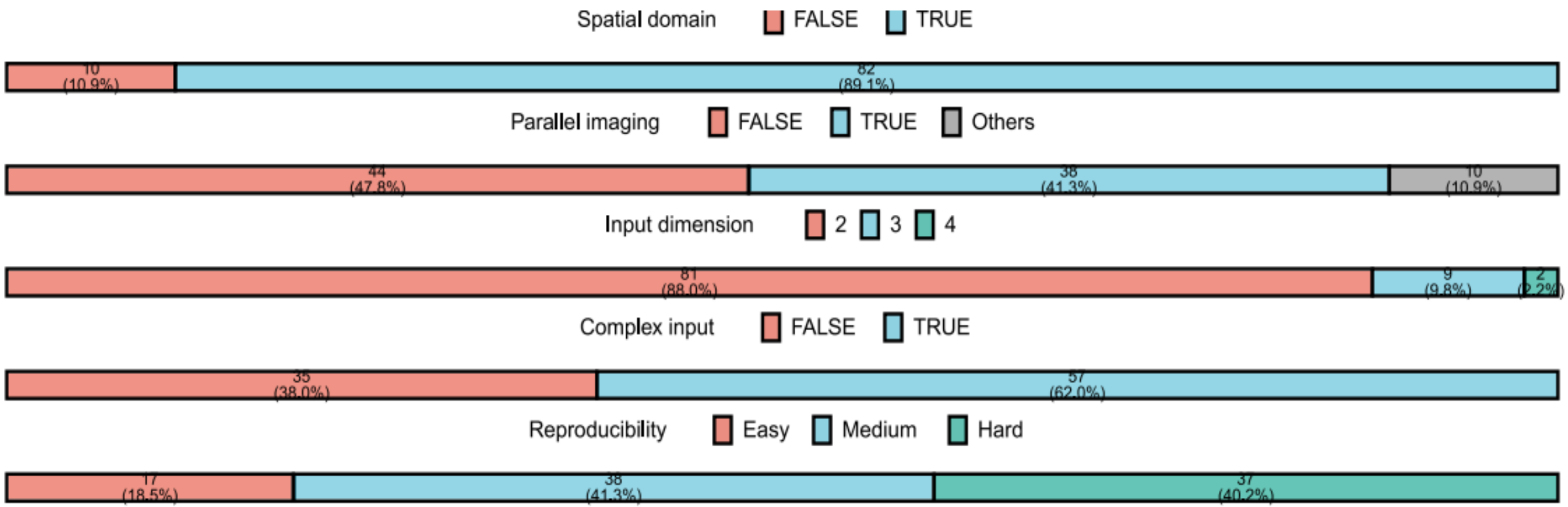
# Key Findings and Highlights

## Key Design Traits



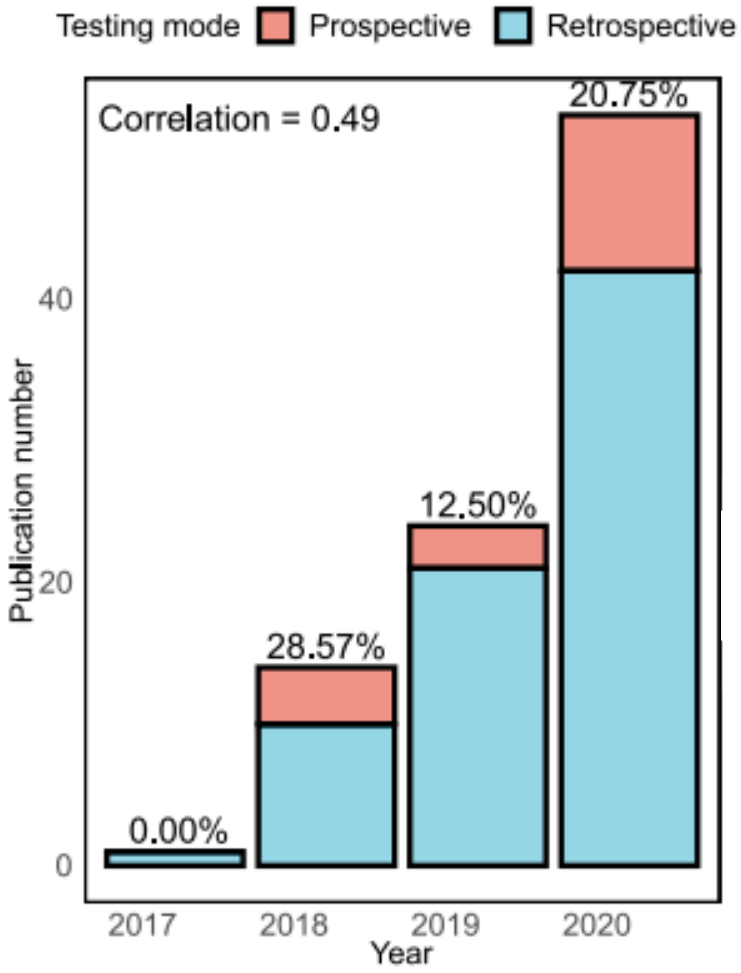
# Key Findings and Highlights

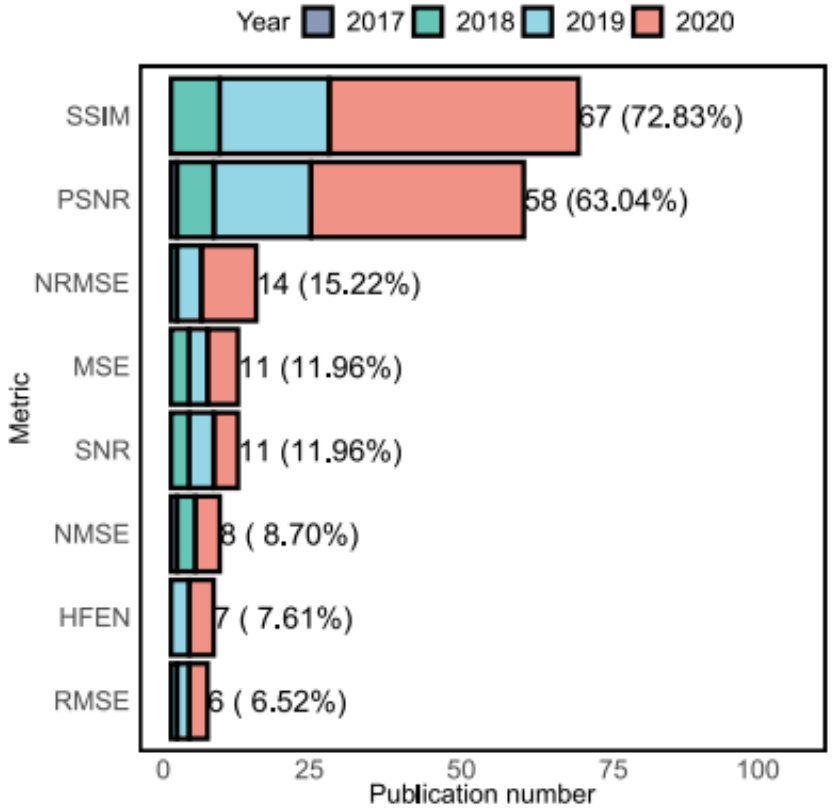
## Input Image Characteristics

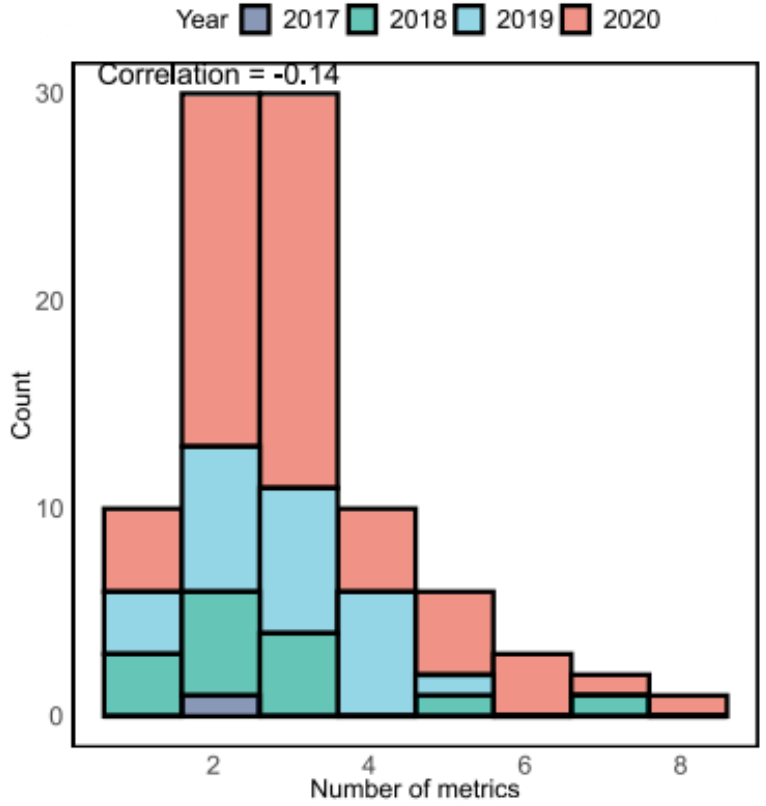


# Key Findings and Highlights

## Performance: Prospective-vs-Retrospective & Performance Metrics

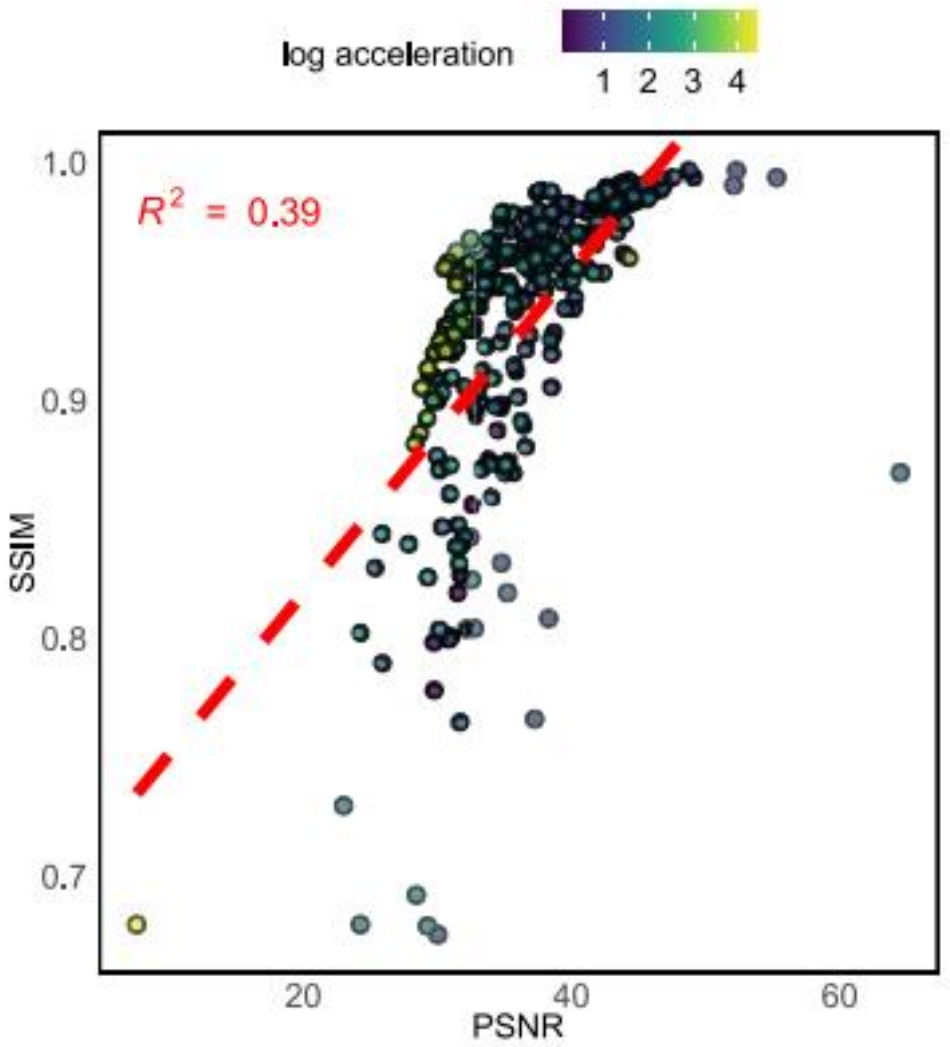


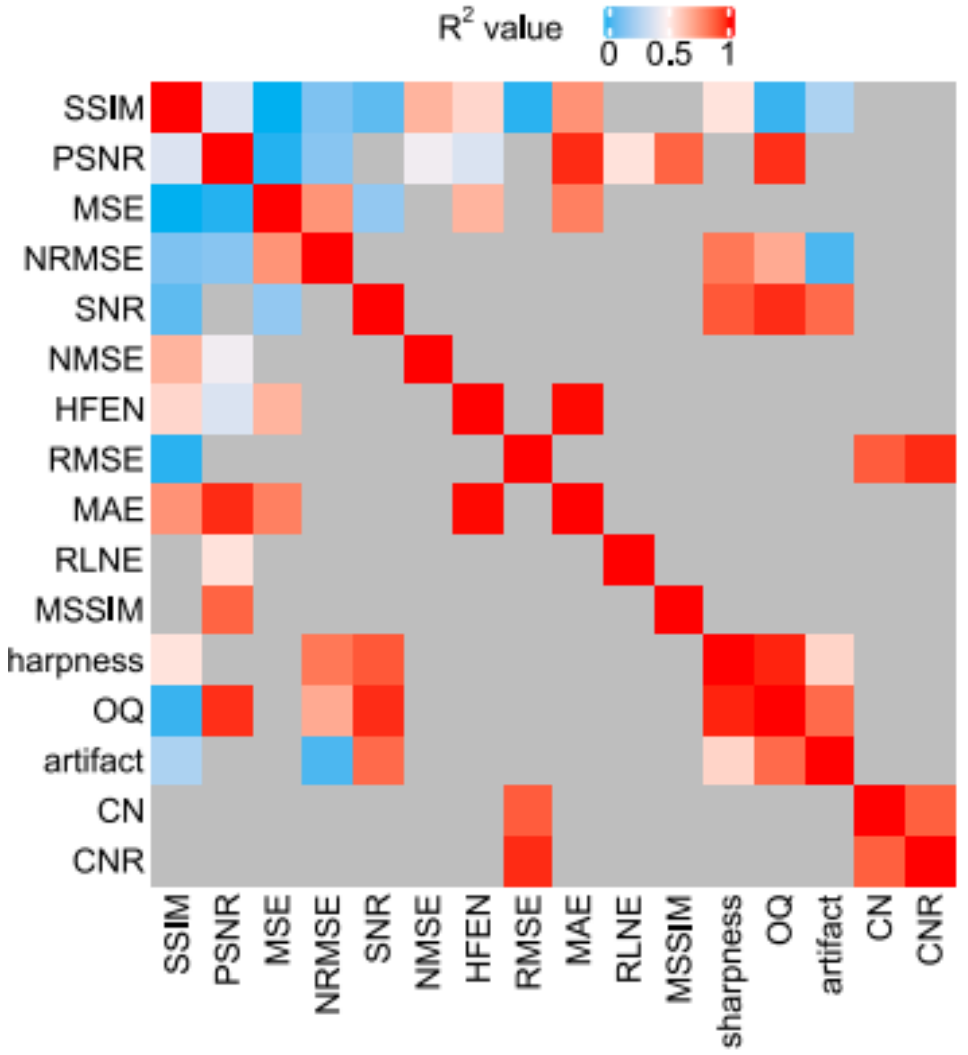



# Key Findings and Highlights

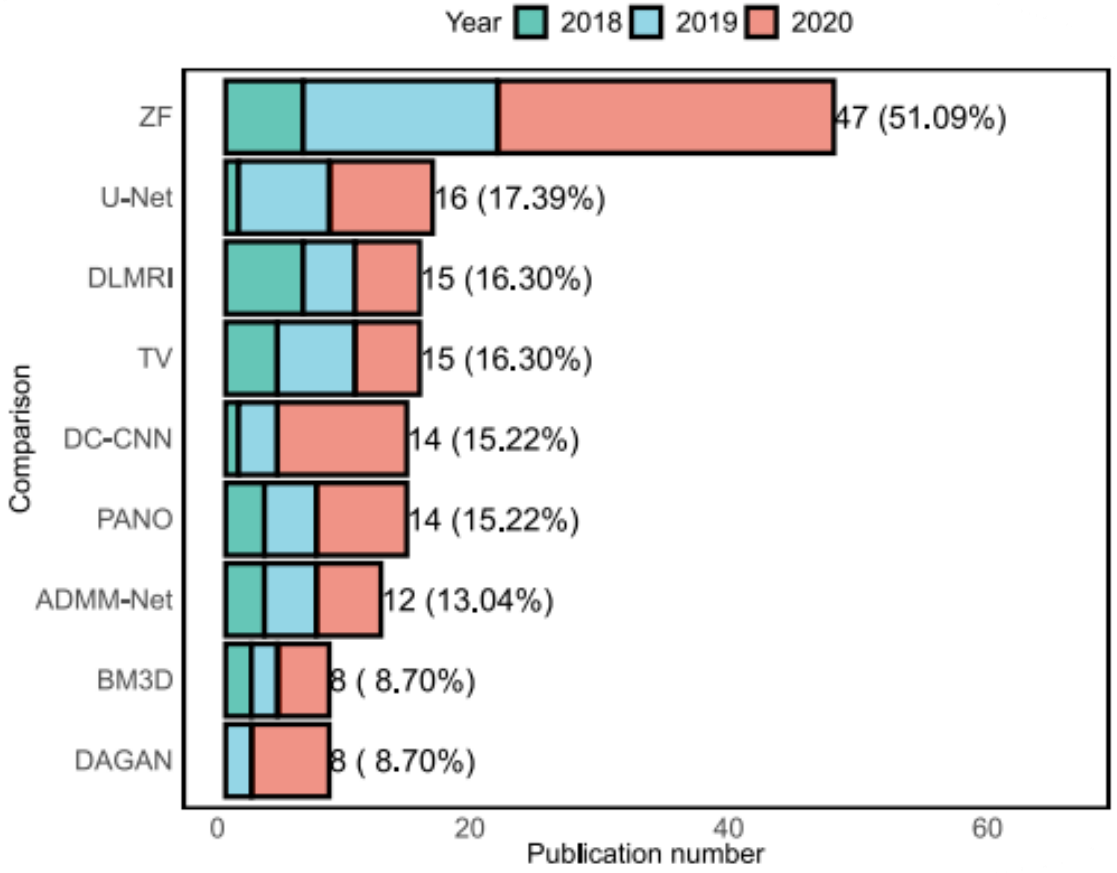
## Performance: Different Metrics comparison and Heatmap

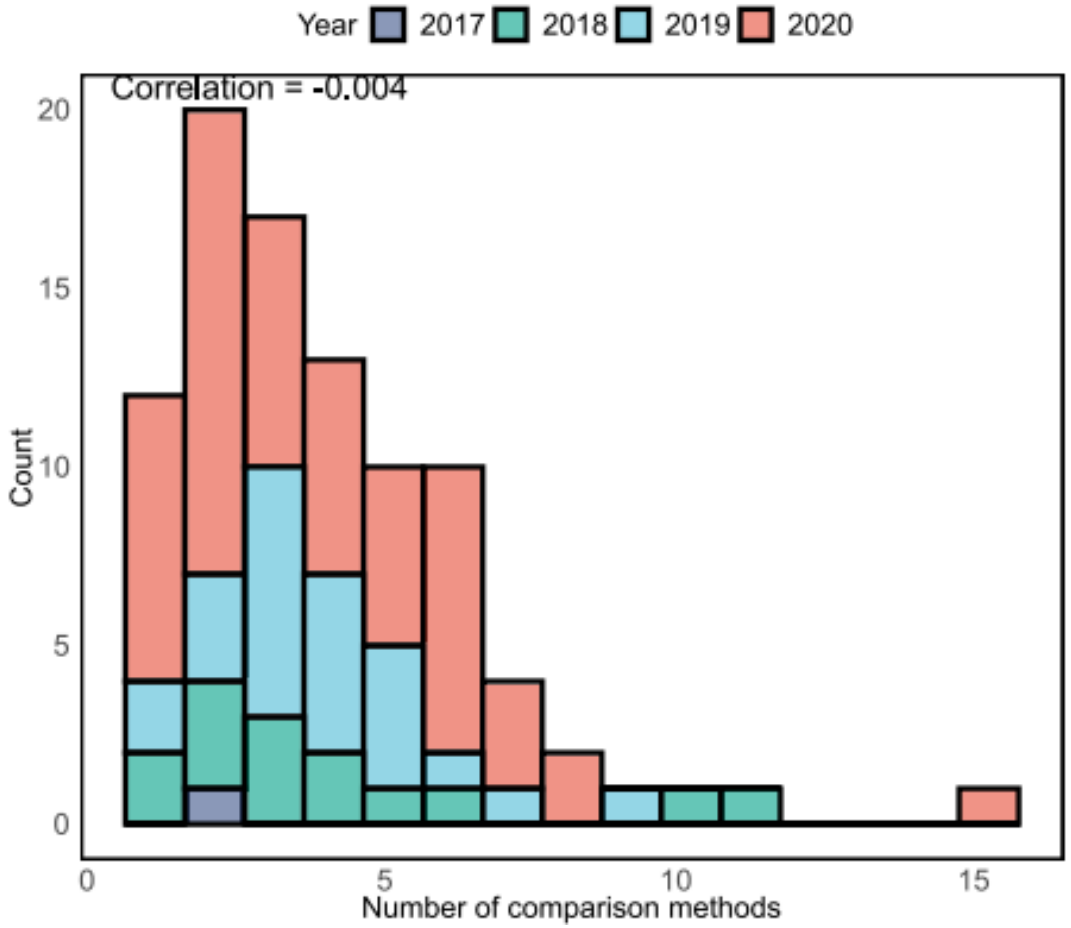


# Key Findings and Highlights

## Performance: Popular models used for comparison



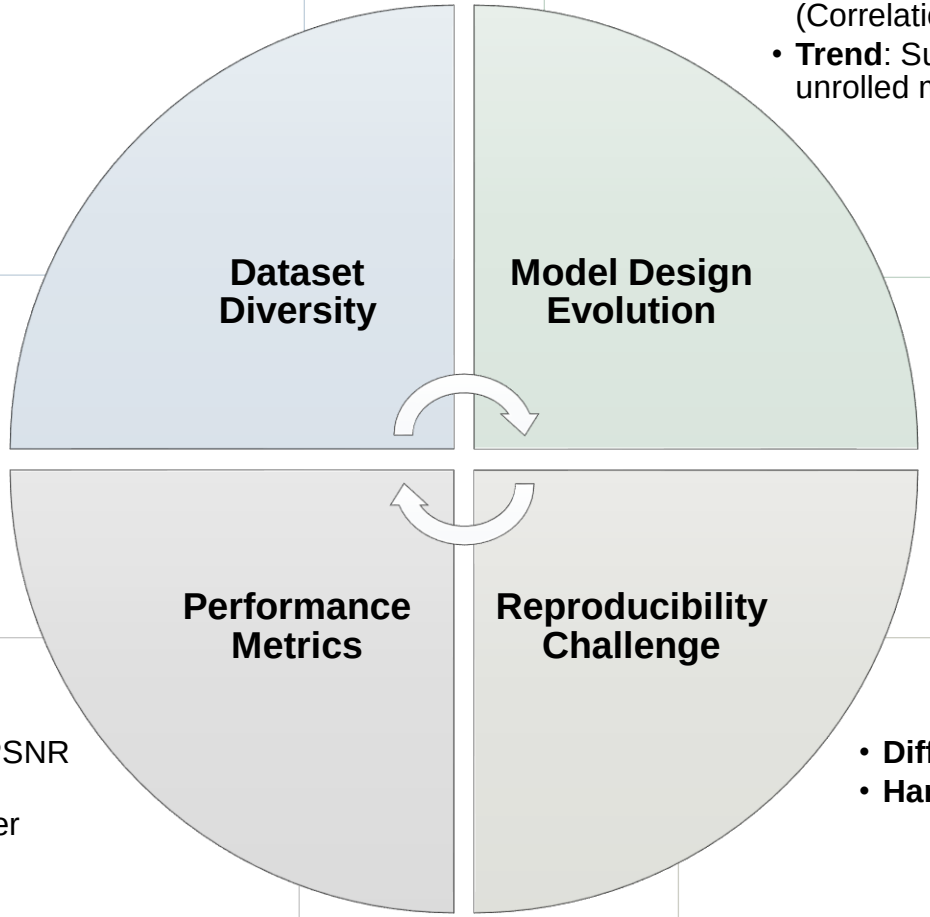



# Key Findings and Highlights

## Summary

- **Private**: 44.6%
- **Public**: 32.6%
- **Both**: 22%

- **U-Net Dominance**: 40% (Correlation with time: 0.87)
- **Trend**: Supervised and unrolled models rising



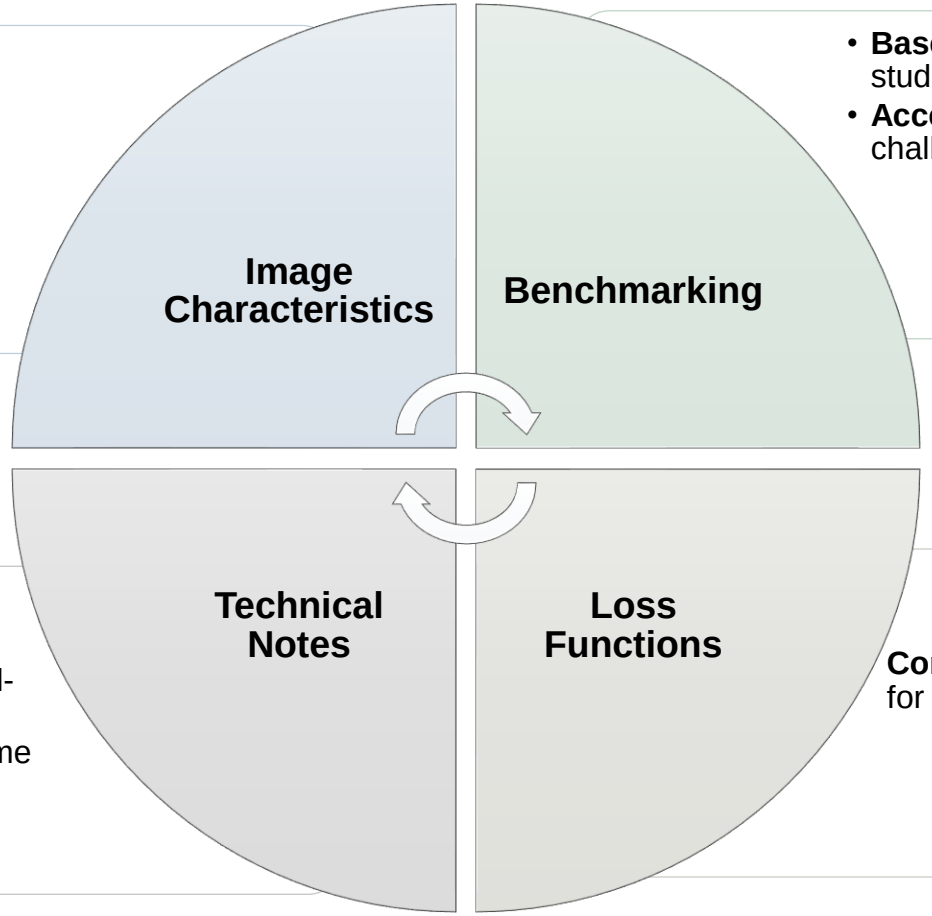

- **Popular**: SSIM and PSNR
- **Sensitivity**: SSIM for lower, PSNR for higher model performance

- **Difficulty**: Increasing
- **Hard(Corr)**: 0.84

# Key Findings and Highlights

## Summary

- **Standard**: 2D, 256x256, T1/T2 weighted
- **Augmentation**: To expand datasets




- **Baseline**: Zero-filling in 51.9% of studies
- **Acceleration Impact**: Higher ratios challenge performance

- **Complex Signal Processing**: Real-imaginary split in 60.9% of models
- **Computation Stats**: Stable over time

**Common**: MSE, L1, L2 (Preference for L1 to reduce oversmoothing)

# Challenges and Outlook

## Challenges:

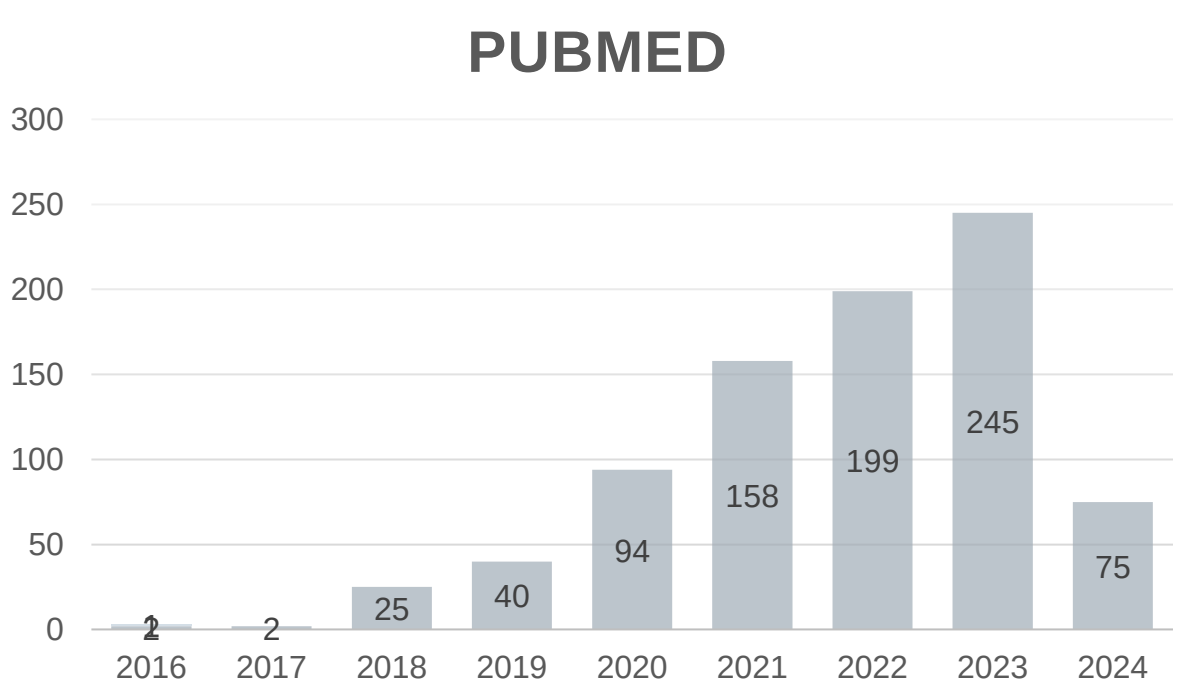
- Large Training Dataset Dependency
- Generalizability
- Training Duration
- Motion Artifact Sensitivity

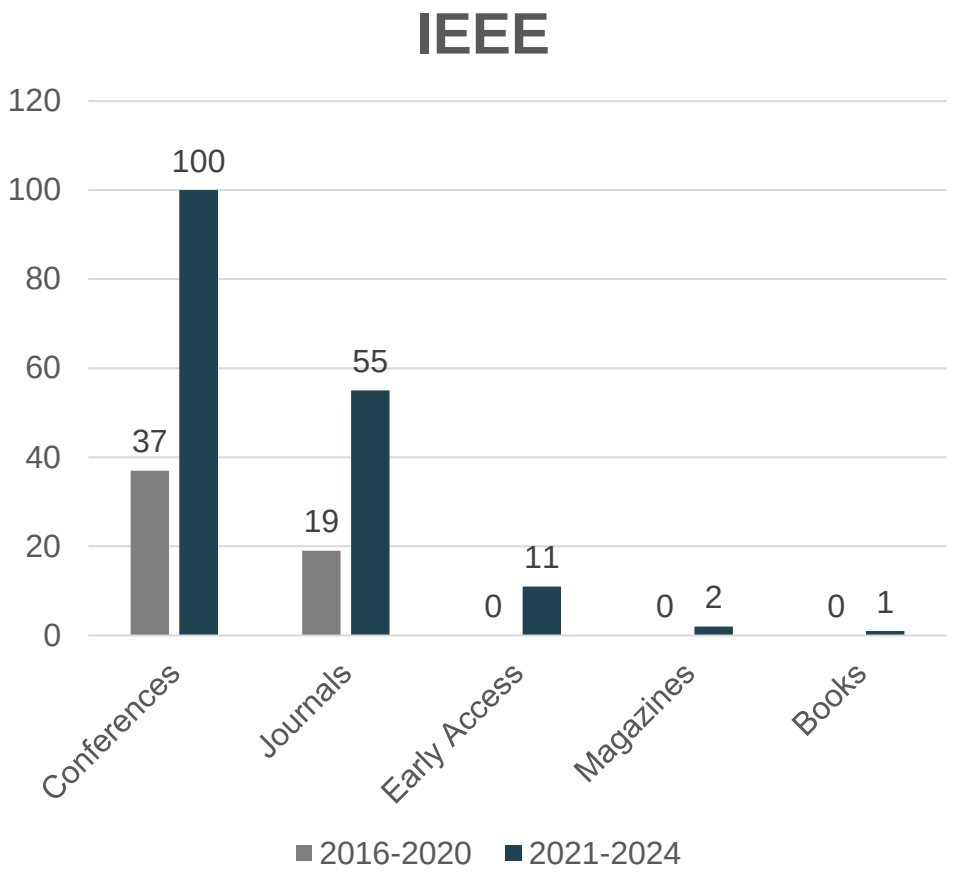
## Outlook:

- Advancement Pace
- Image Exploration
- Benchmark Creation
- Healthcare Impact

# Beyond the Paper

Title/Abstract containing keywords like “MRI”, “reconstruction” & “deep learning”



# Beyond the Paper

## Recent Research Trends: Meta-Analysis Overview (2021-2023)

**Architecture**

Diverse AI/ML architecture used.

Adaptive-CS-Net, Cascade-Net, CRNN-MRI, Kalman-Filter, highly tuned PG-DL, C-SENSE AI.

**Performance metric**

SSIM,PSNR widely used.

SNR, ERD, MSE, convergence analysis, IQ, Noise, Motion artifacts, lesion detection, diagnostic certainty, apparent SNR, apparent CNR, lesion size, line profile. Qualitative metric still used in niche cases.

**Region**

cardiac, knee, shoulder, prostate.

**Input dimension**

Mostly 2D.

**Acceleration ratio achieved**

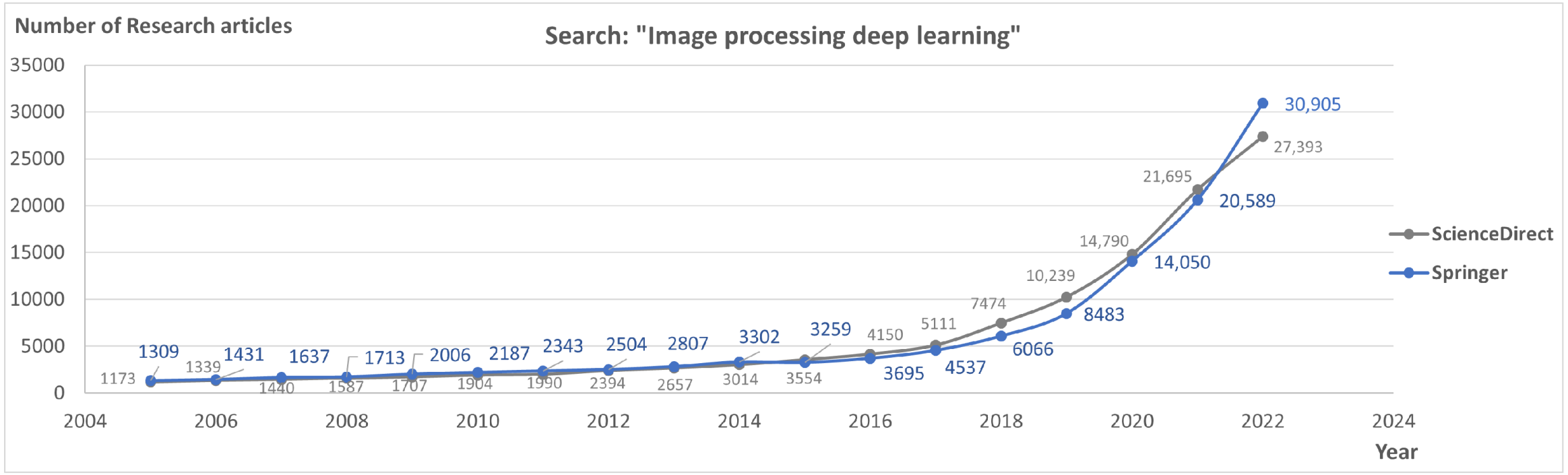
2-13 times.

**Compared with**

ResNet.

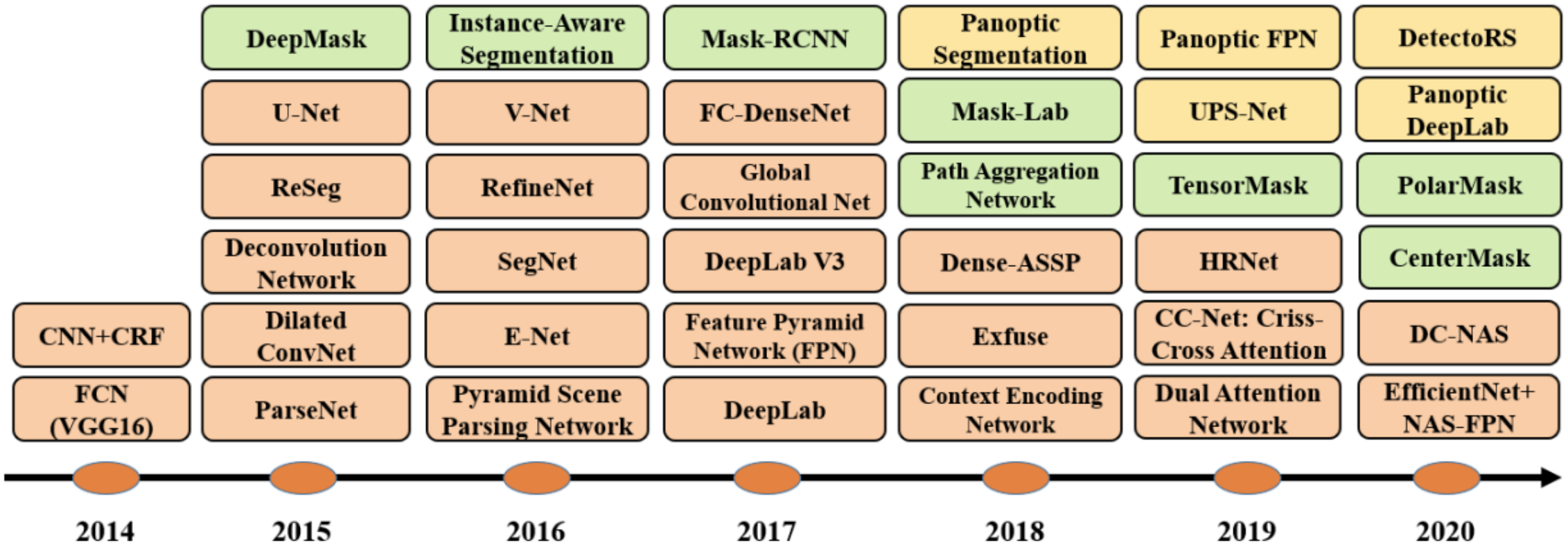
# Beyond the Paper

## Search Trend (source 7)



# Beyond the Paper

The timeline of DL-based segmentation algorithms for 2D images, from 2014 to 2020. (source 6)



# References


1. Chen, Y., Schönlieb, C.-B., Liò, P., Leiner, T., Dragotti, P. L., Wang, G., Rueckert, D., Firmin, D., & Yang, G. (2021). AI-based Reconstruction for Fast MRI – A Systematic Review and Meta-analysis. Retrieved from https://arxiv.org/ftp/arxiv/papers/2112/2112.12744.pdf

2. Deb, A. (2023, November 27). Unveiling the Power of Super-Resolution: A Comparative Analysis of U-Net and SRGAN. Medium. Retrieved from https://medium.com/@ankandeb0120/unveiling-the-power-of-super-resolution-a-comparative-analysis-of-u-net-and-srgan-b0b91a602419

3. Gainetdinov, A. (n.d.). Diffusion Models vs. GANs vs. VAEs: Comparison of Deep Generative Models. Towards AI. Retrieved from https://pub.towardsai.net/diffusion-models-vs-gans-vs-vaes-comparison-of-deep-generative-models-67ab93e0d9ae

4. Intel Community. (n.d.). Compressed Sensing + AI = Faster, High-Quality Medical Imaging. Retrieved from https://community.intel.com/t5/Blogs/Tech-Innovation/Artificial-Intelligence-AI/Compressed-Sensing-AI-Faster-High-Quality-Medical-Imaging/post/1335684

5. IEEE Xplore Digital Library. Retrieved from https://ieeexplore.ieee.org/

6. Minaee, S., Boykov, Y., Porikli, F., Plaza, A., Kehtarnavaz, N., & Terzopoulos, D. (2020). Image Segmentation Using Deep Learning: A Survey. arXiv. Retrieved from https://arxiv.org/pdf/2001.05566.pdf

7. Valente, J., António, J., Mora, C., & Jardim, S. (2023). Developments in Image Processing Using Deep Learning and Reinforcement Learning. Journal of Imaging, 9(10), 207. MDPI. Retrieved from https://www.mdpi.com/2313-433X/9/10/207

8. MRI Brain (Summary): https://radiopaedia.org/articles/mri-brain-summary

# References

## Papers used for short survey


1. Reconstruction of shoulder MRI using deep learning and compressed sensing: a validation study on healthy volunteers. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10600091/
2. From Compressed-Sensing to Artificial Intelligence-Based Cardiac MRI Reconstruction : https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7051921/
3. A predictive signal model for dynamic cardiac magnetic resonance imaging : https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10290992/
4. Revisiting ℓ1-wavelet compressed-sensing MRI in the era of deep learning: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9388129/
5. Feasibility of AI-assisted compressed sensing protocols in knee MR imaging: a prospective multi-reader study: https://pubmed.ncbi.nlm.nih.gov/37382615/
6. A deep learning-based reconstruction approach for accelerated magnetic resonance image of the knee with compressed sense: evaluation in healthy volunteers: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10230385/
7. Prospectively Accelerated T2-Weighted Imaging of the Prostate by Combining Compressed SENSE and Deep Learning in Patients with Histologically Proven Prostate Cancer: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9738899/
8. Promoting fast MR imaging pipeline by full-stack AI: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10762466/

# Thank you for the attention!

## Next: Questions