



Edge SpAIce

Edge SpAIce: Deep Neural Network Simplification Pipeline for On-board Data Reduction

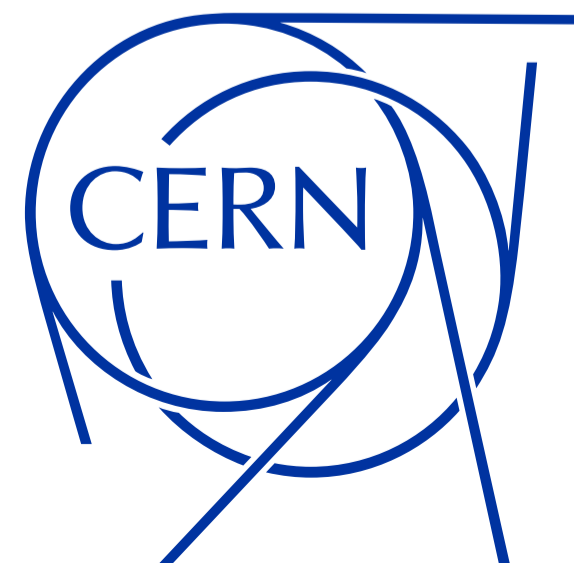
Nimesh TAHALOOA

EDHPC 2025

17.10.2025



AGENIUM
SPACE



National
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University
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Improve Marine Plastic Litter Detection using Deep Neural Networks in Space

TRAIN



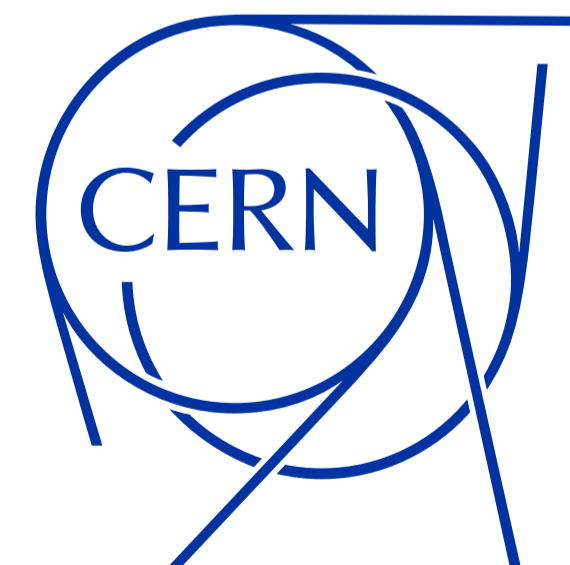
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SIMPLIFY



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DEPLOY



FLY



ENDUROSAT



Outline

1/ AI for Earth Observation

1.1/ Pruning

1.2/ Distillation

1.3/ Model architectures

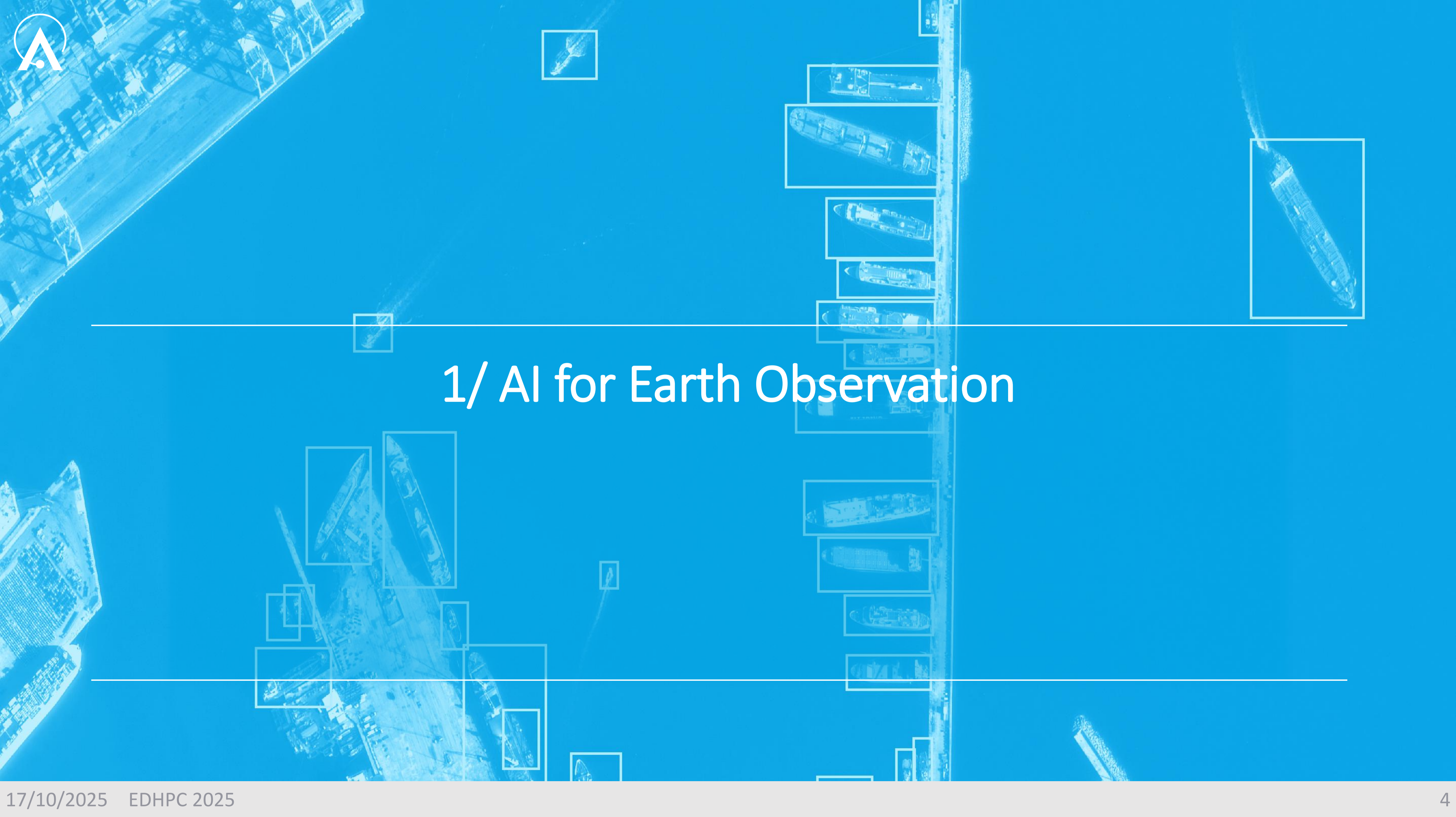
2/ Results

2.1/ Benchmark dataset (PascalVOC)

2.2/ EO dataset (Internal airplanes dataset)

2.3/ Test use case (MADOS)

3/ Conclusion



1/ AI for Earth Observation

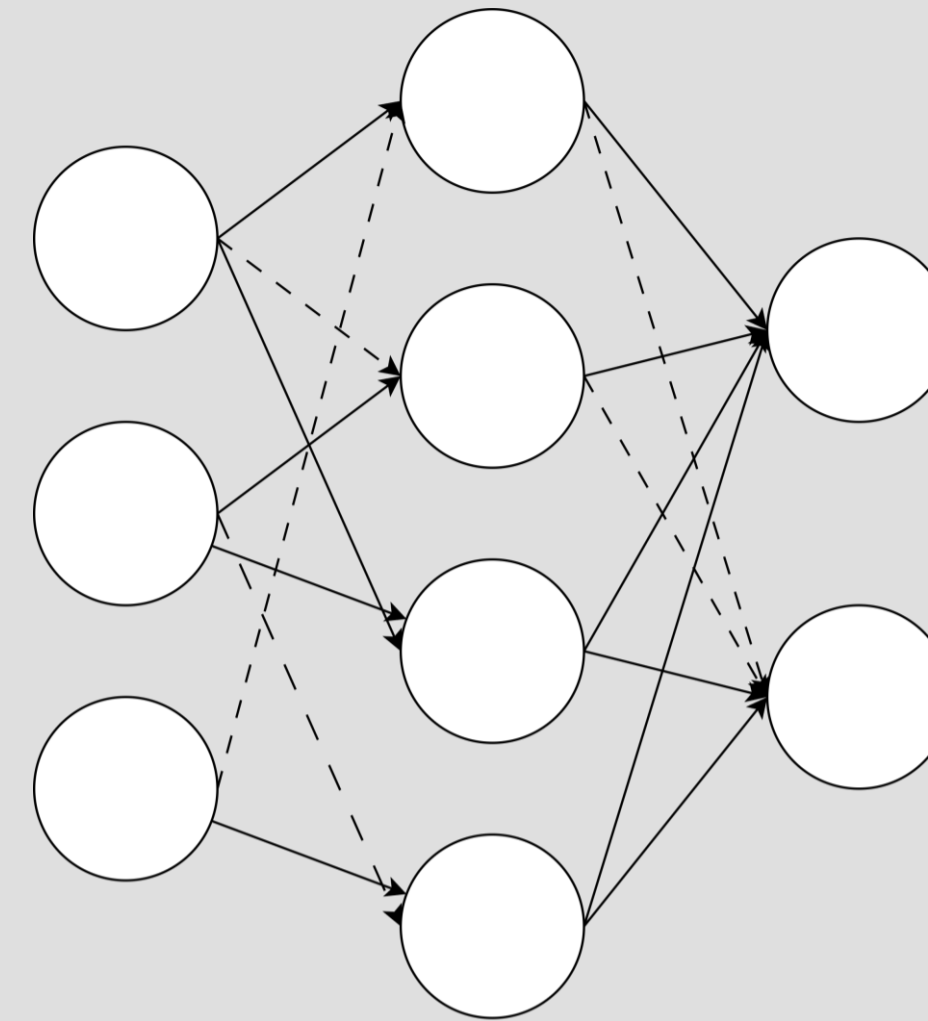


AI for Earth Observation Pruning

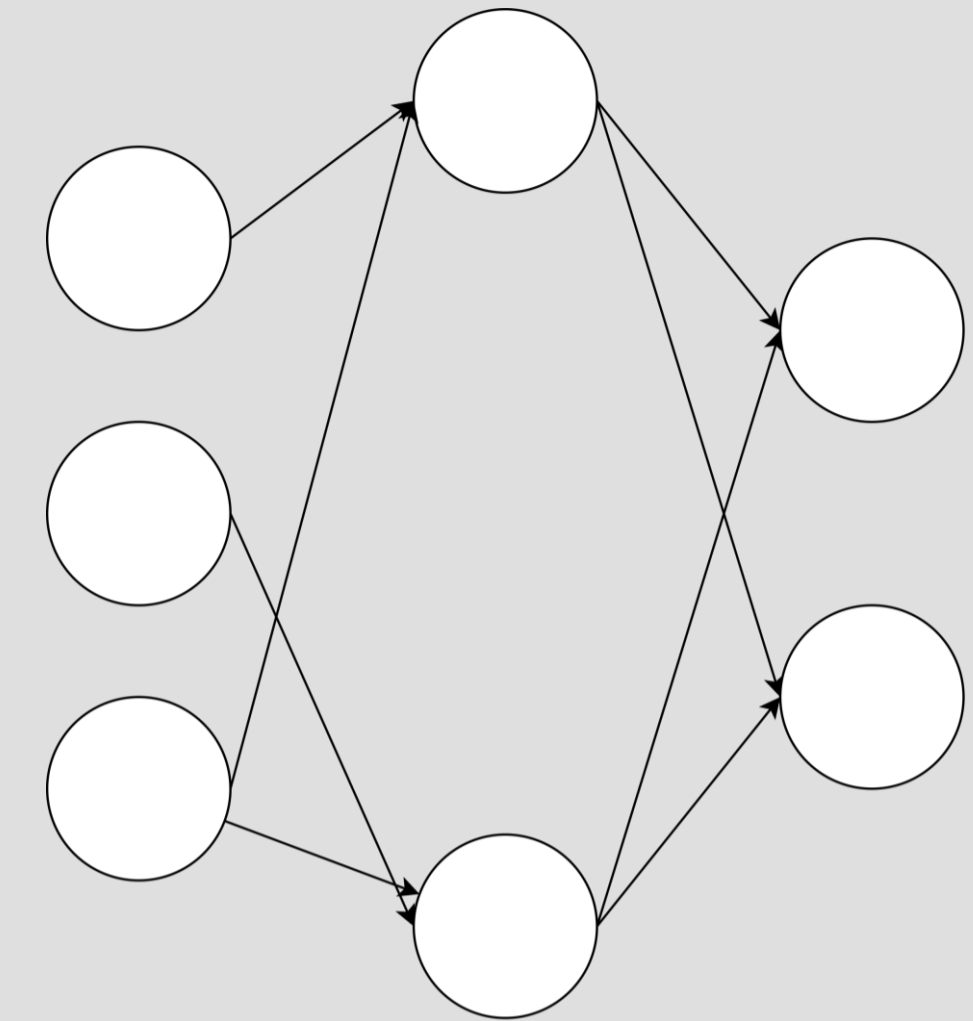
Simplification technique with many variants

Remove “ineffective” connections or nodes

Prune once or iteratively?



Unstructured pruning



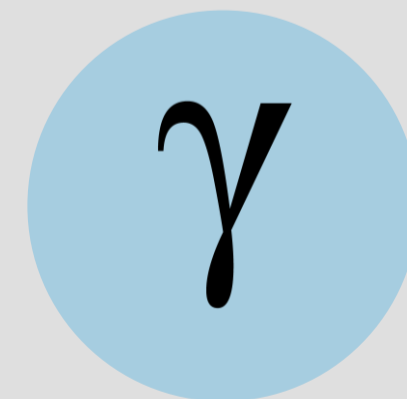
Structured pruning



RANDOM PRUNING
(BASELINE)



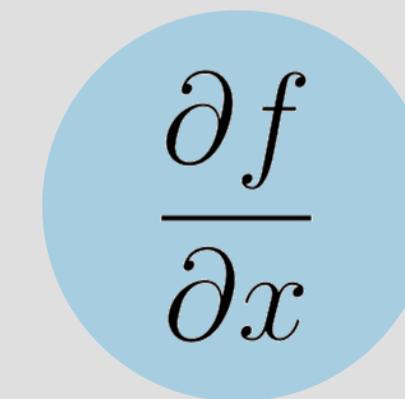
MAGNITUDE-BASED



BATCH-NORM SCALE-BASED



FILTER PRUNING VIA
GEOMETRIC MEDIAN



TAYLOR APPROXIMATION

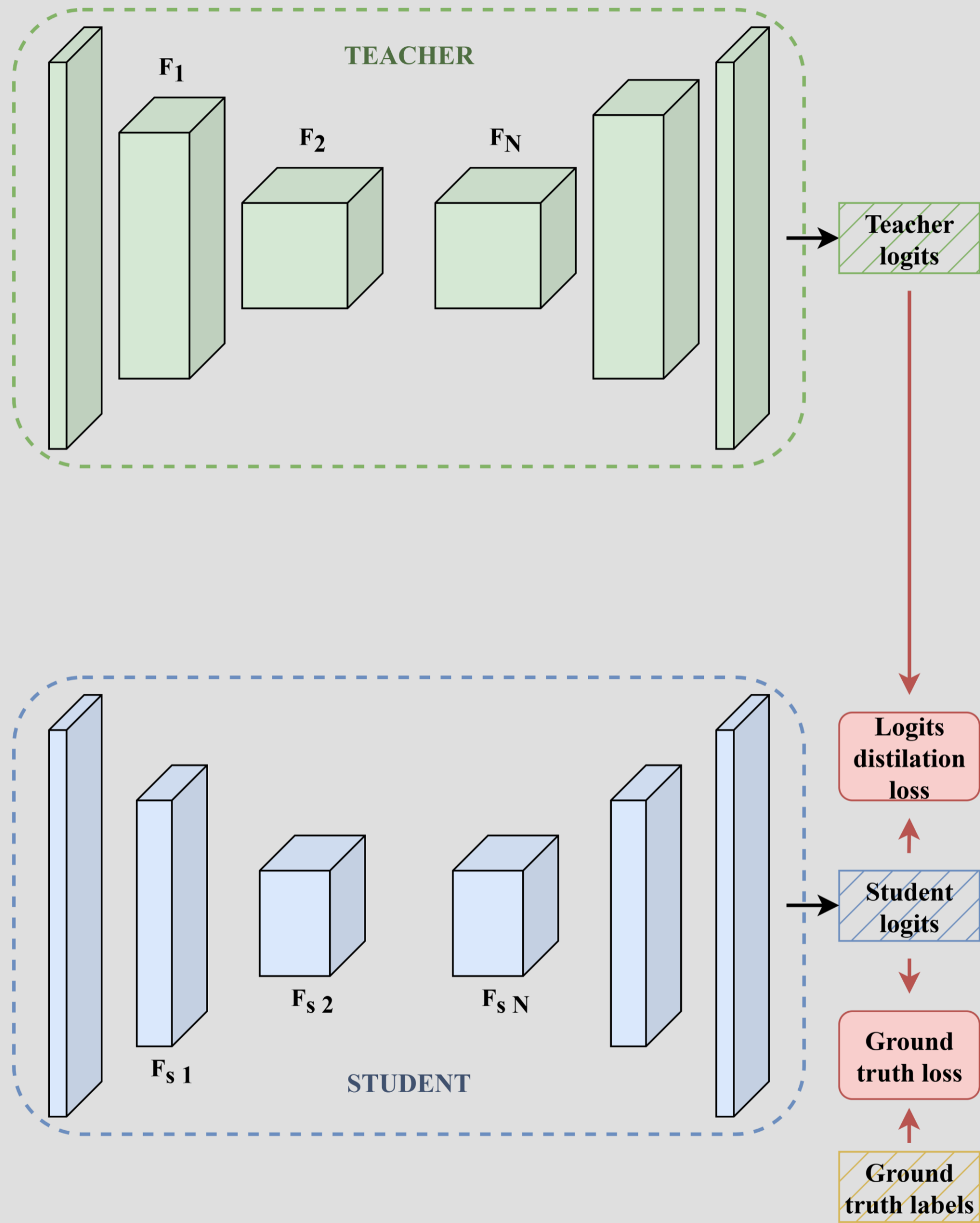


LAYER-ADAPTIVE SPARSITY FOR
MAGNITUDE-BASED PRUNING

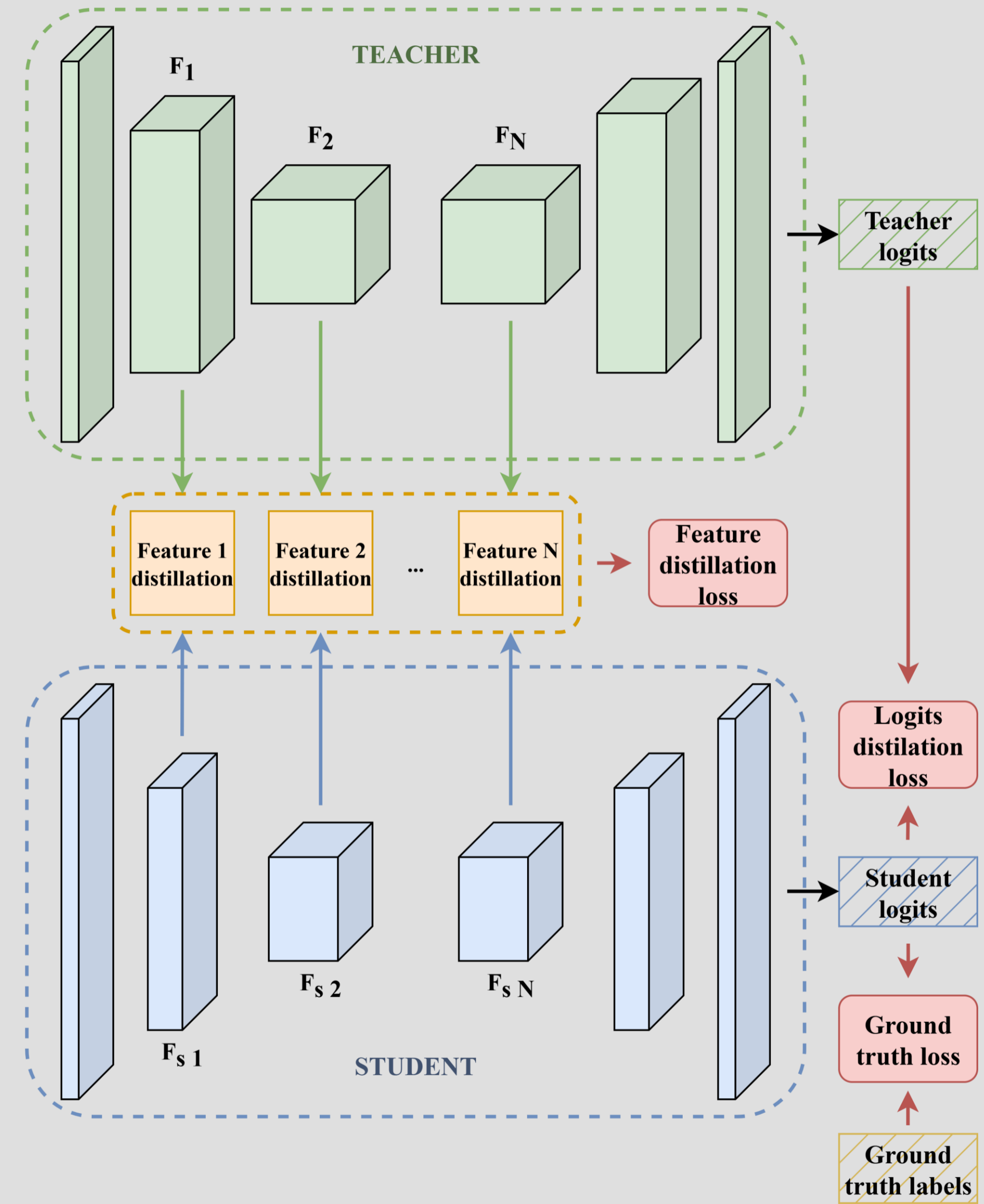


AI for Earth Observation

Distillation



Black-box distillation



Intermediate features distillation



AI for Earth Observation

Model architectures

Objective: Image semantic segmentation

Teacher model

Feature Pyramid Network with EfficientNet-B4 backbone
(27M parameters)

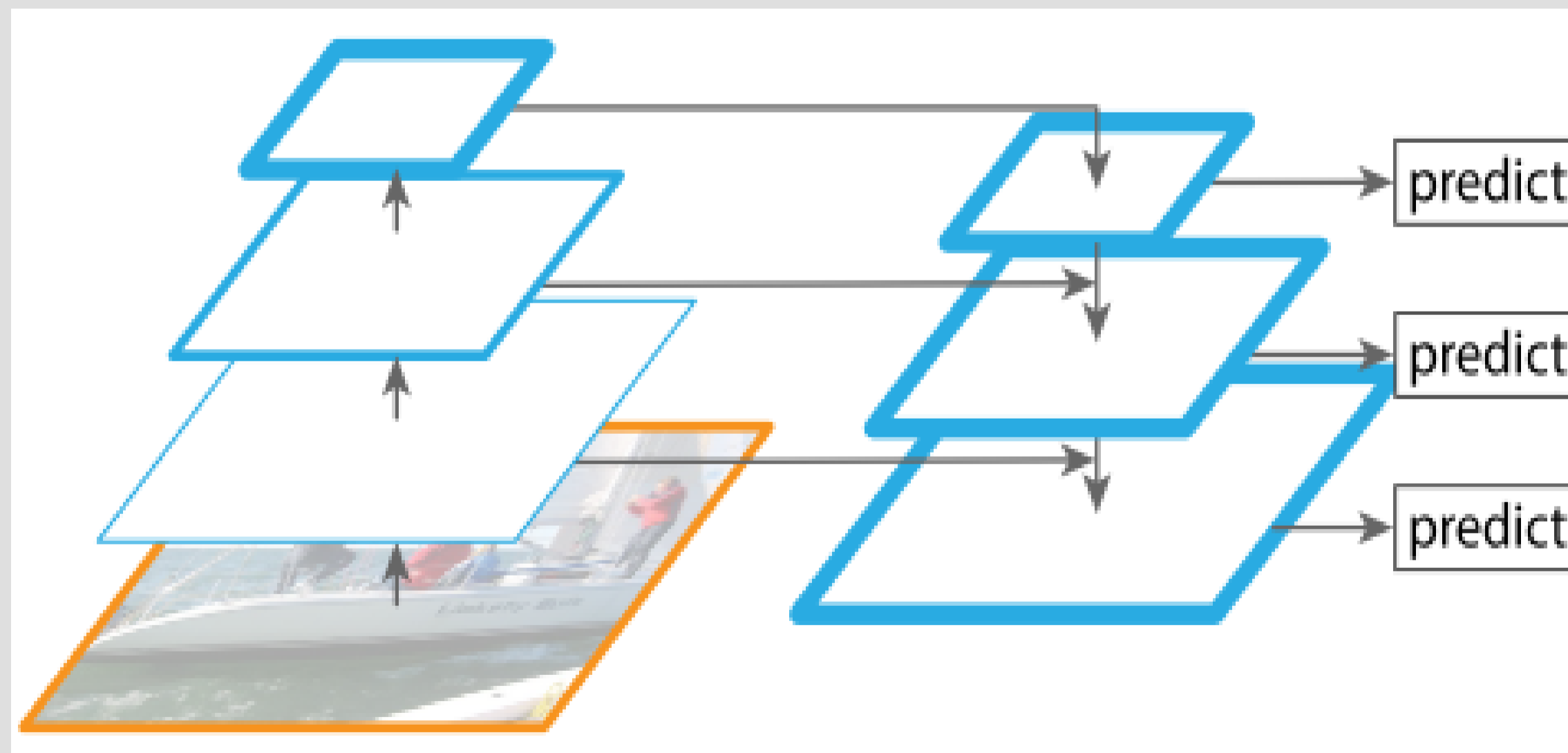


Image source: Feature Pyramid Networks for Object Detection (2017)

Student model

“Tiny” U-Net
(100k parameters)

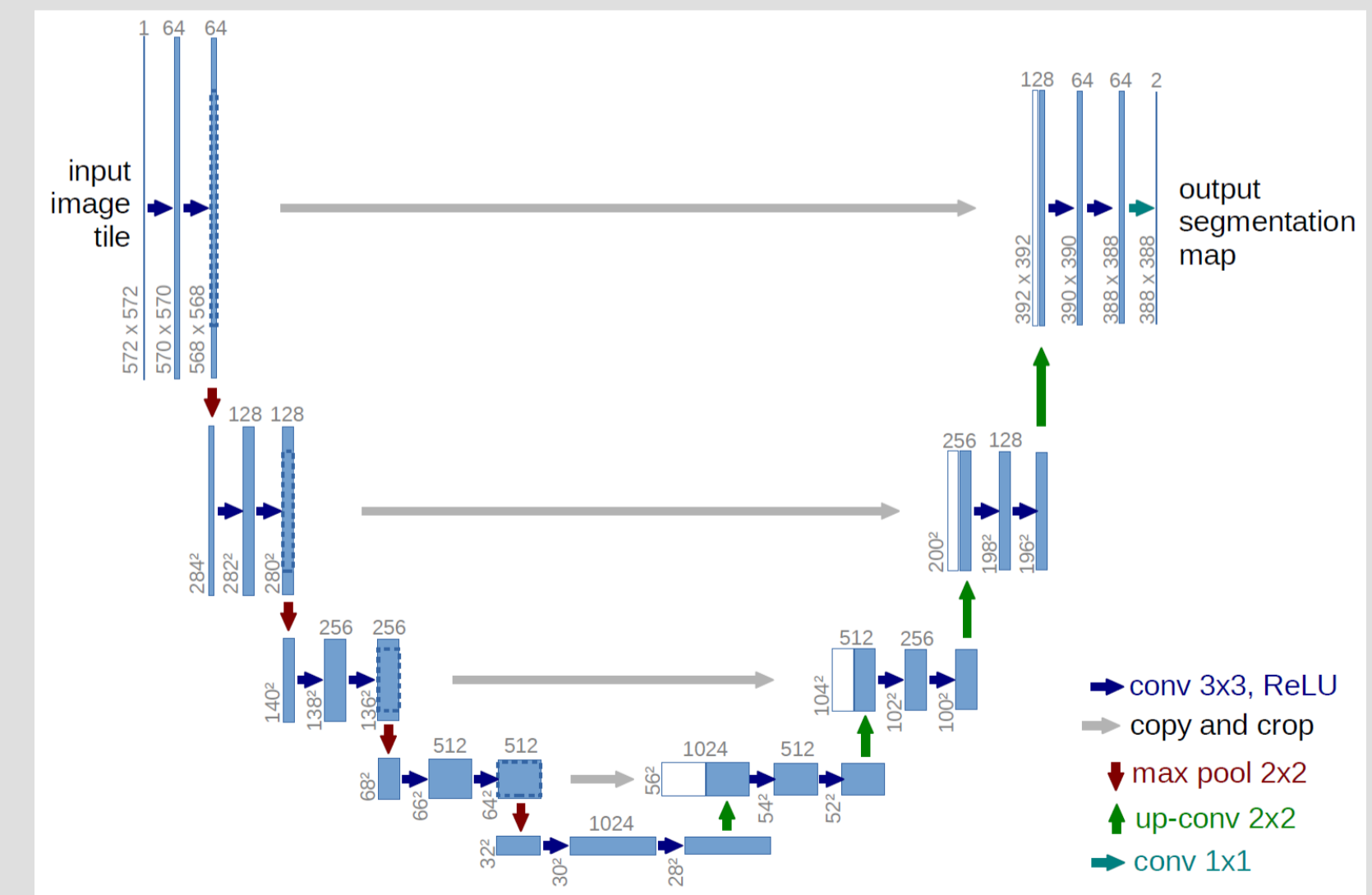
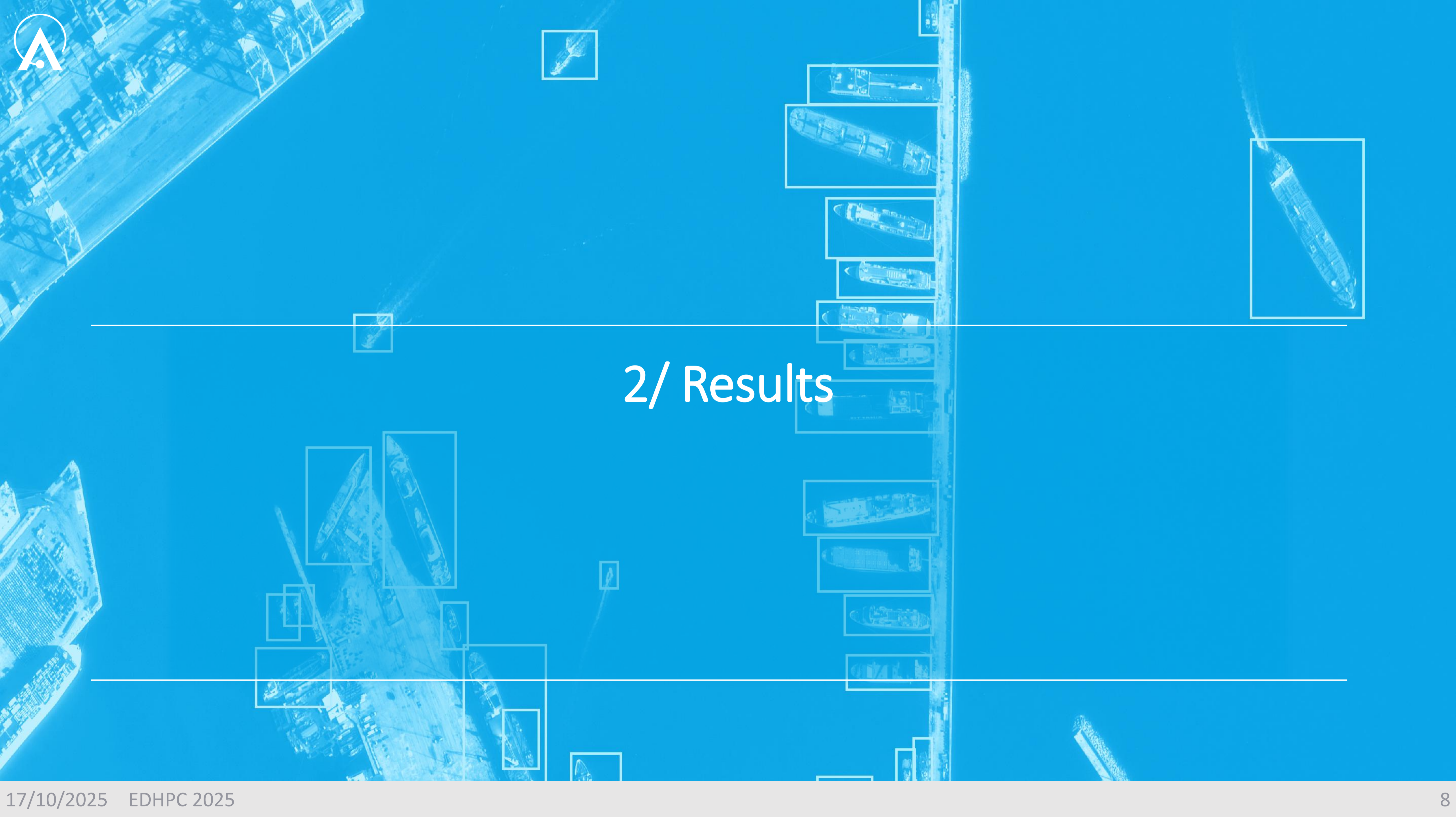


Image source: U-Net: Convolutional Networks for Biomedical Image Segmentation (2015)



2/ Results



Results

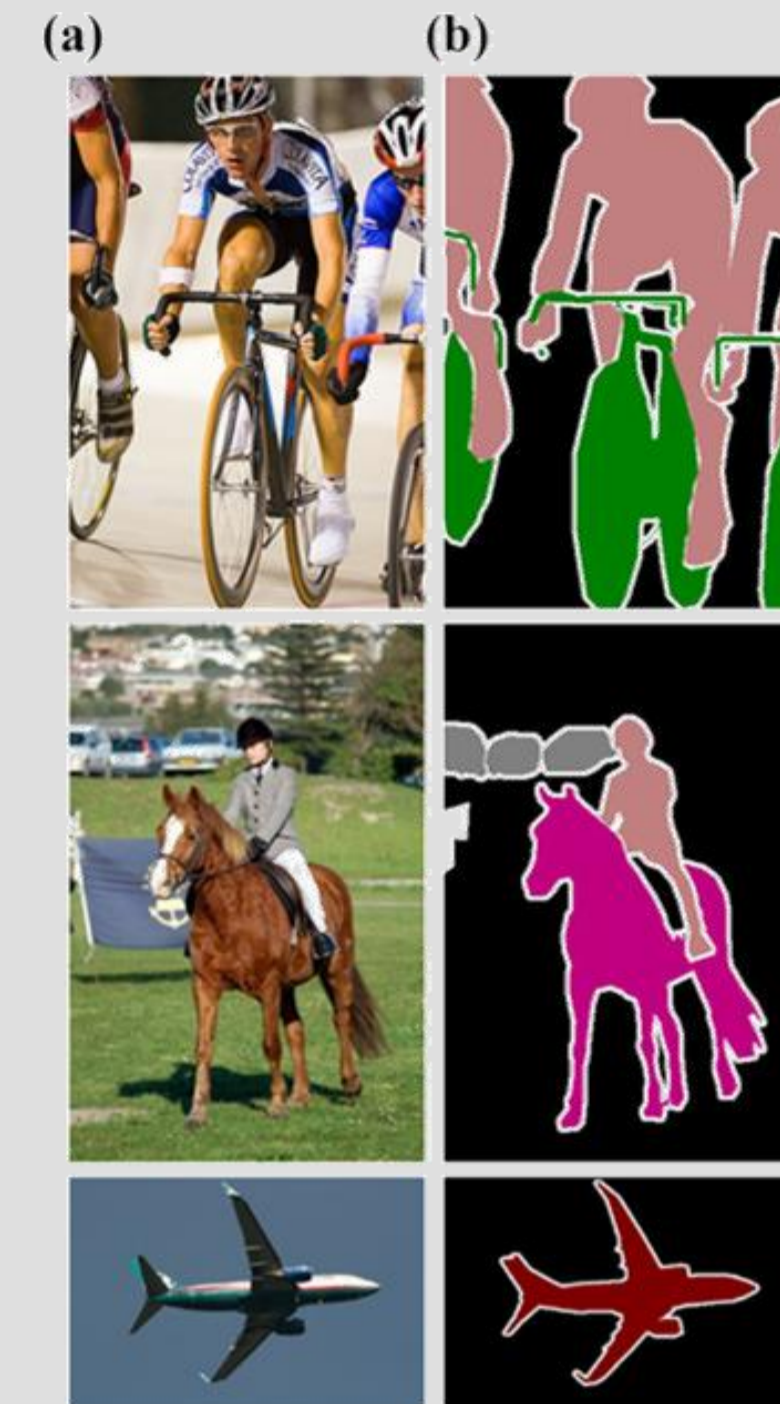
Benchmark dataset (PascalVOC) – Description

Dataset characteristics

- 21 classes for image semantic segmentation
- Around 180k images
- 131M object pixels (1.2% of total pixels)

Dataset Justification

- Well-established AI benchmark dataset
- Many diverse classes
- Natural images with rich context



[Image source: Multilevel feature fusion dilated convolutional network for semantic segmentation](#)



Results

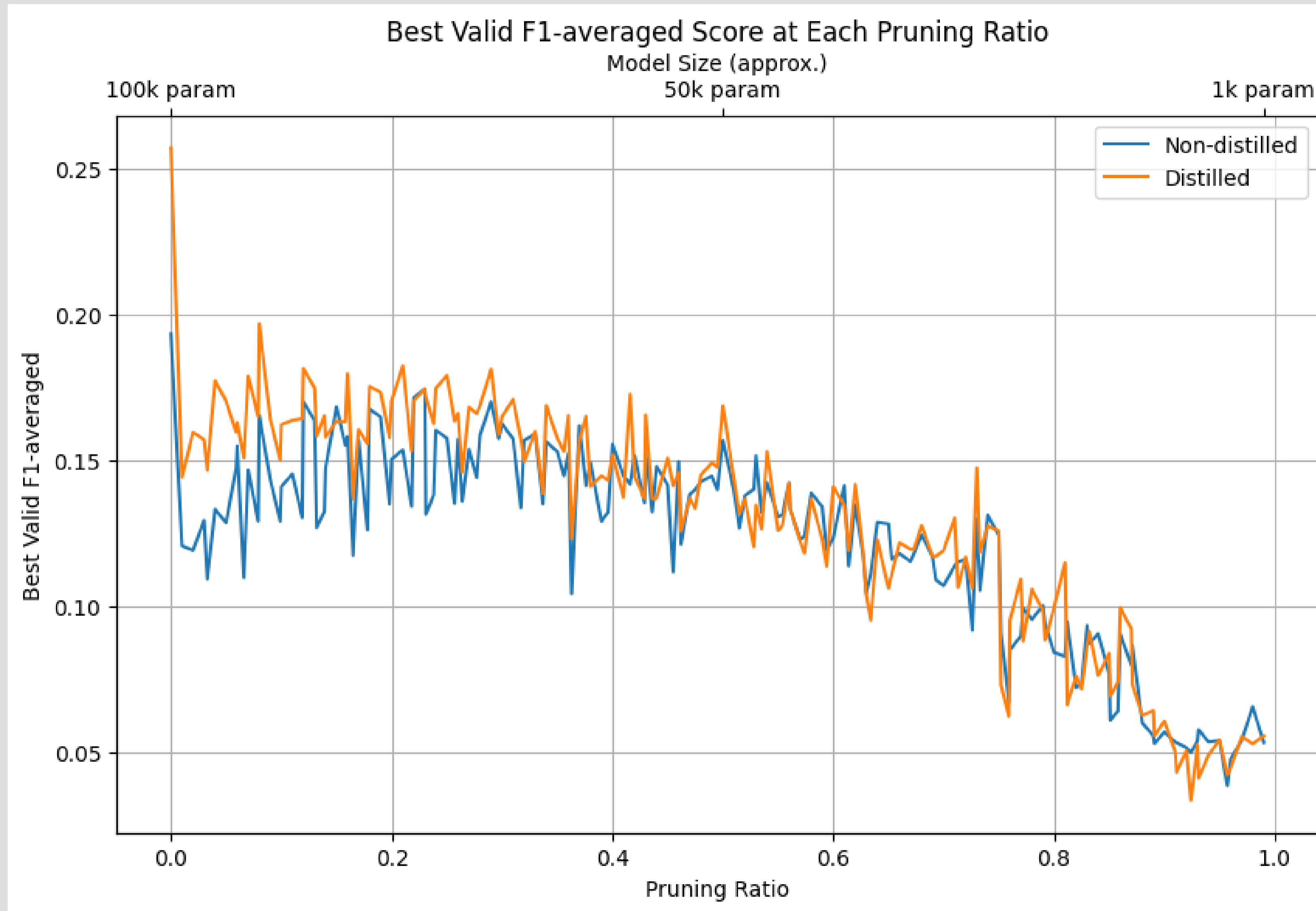
Benchmark dataset (PascalVOC) – Distillation scores

Method		Score (Valid)	
		mIoU	F1-score
Teacher model (27M parameters)		0.65	0.76
Student model (from scratch) (100k parameters)		0.13	0.19
Distillation (100k parameters)	Black-Box	0.17	0.26 (+37%)
	Feature	0.17	0.25 (+32%)



Results

Benchmark dataset (PascalVOC) – Pruning scores





Results

EO dataset (Internal airplanes dataset) – Description

Dataset characteristics

- 9 classes for image segmentation (background + 8 types of aerial vehicles)
- Around 2600 objects of interest
- High resolution dataset

Dataset Justification

- Earth Observation dataset
- Low class diversity





Results

EO dataset (Internal airplanes dataset) – Distillation scores

Method		Validation F1-score
Teacher model (27M parameters)		0.85
Student model (from scratch) (100k parameters)		0.76
Distillation (100k parameters)	Black-Box	0.78 (+2.6%)
	Feature	0.82 (+7.9%)

Note: Pruning on the Airplanes DB is a WIP



Results

Test dataset (MADOS) – Description

Dataset characteristics

- 15 classes describing the state of the water and objects present
- Sentinel-2 imagery
- <https://marine-pollution.github.io/>
- 1.5M object pixels (0.9% of total pixels)

Dataset Justification

- Earth Observation dataset
- Scarcity of objects of interest → often the case in EO

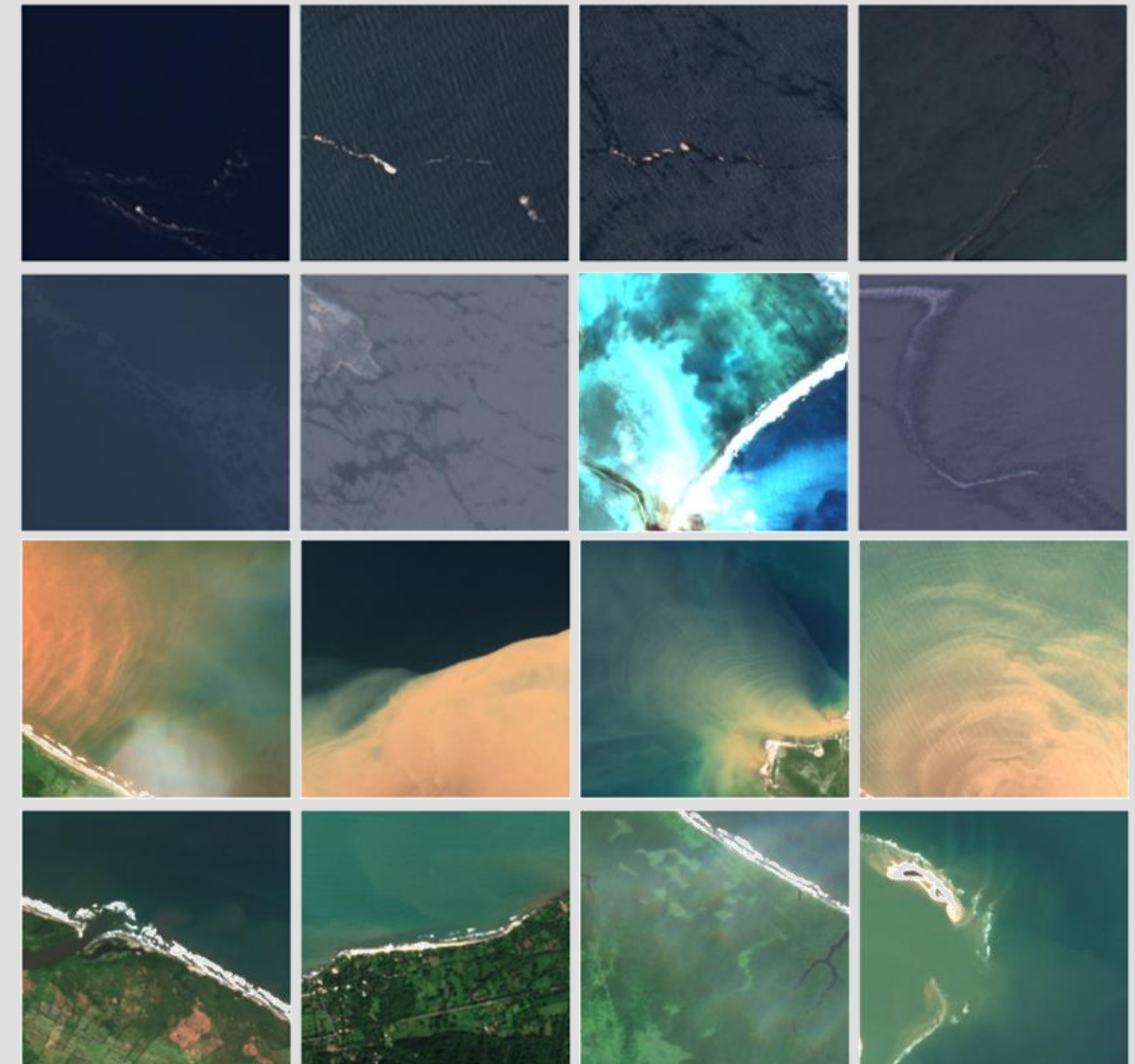


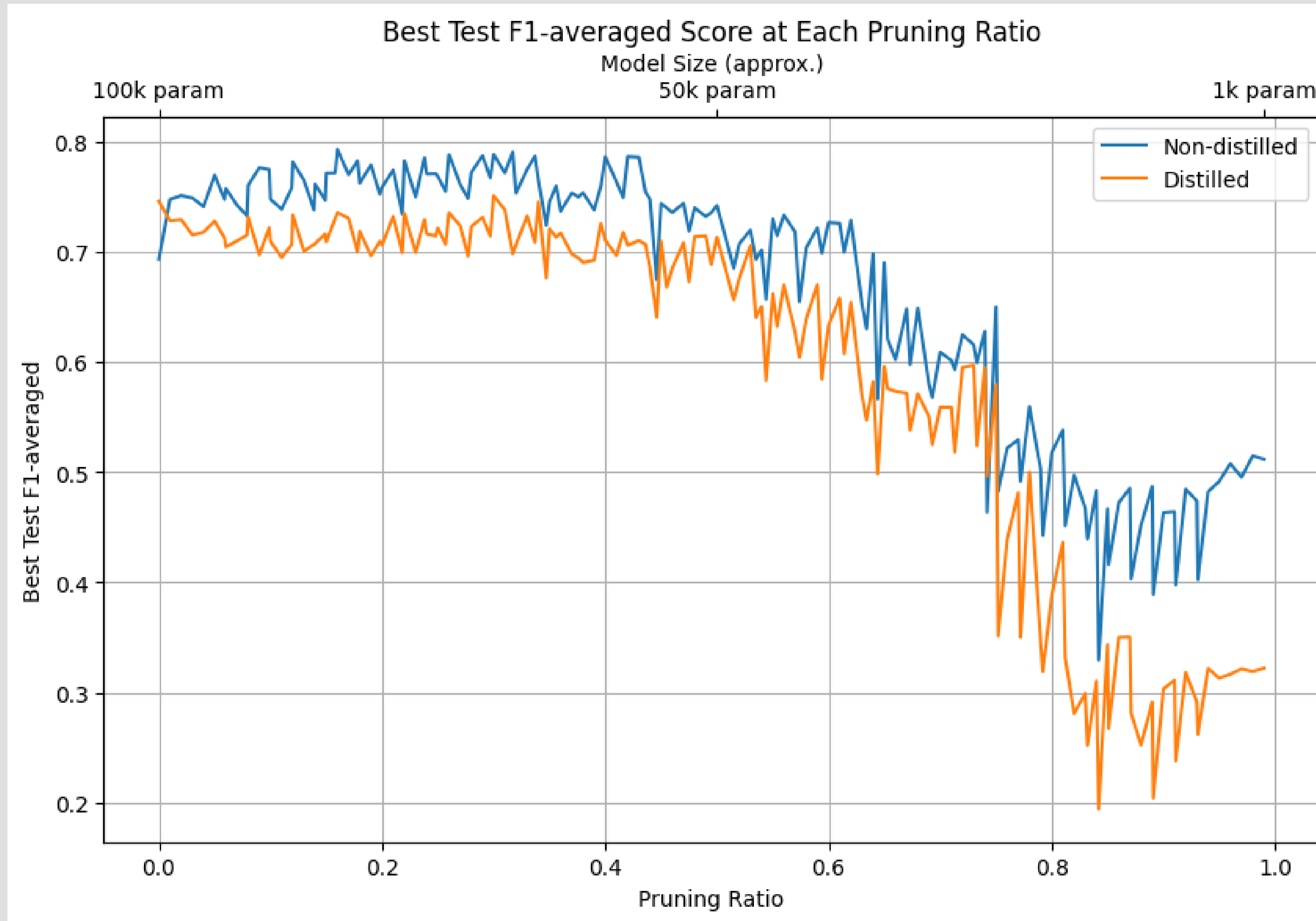
Image source: <https://marine-pollution.github.io/>

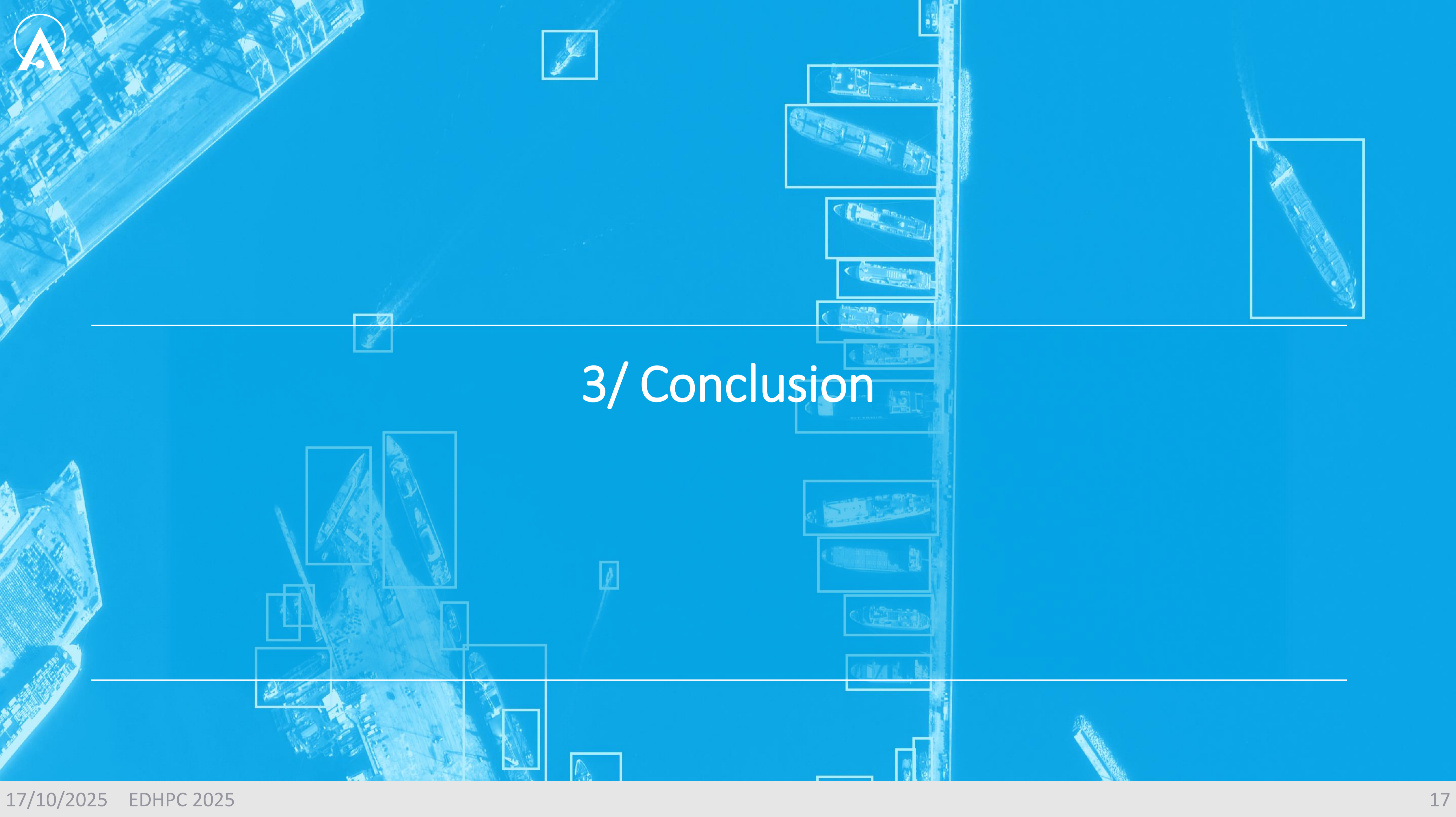
Method		Validation F1-score
Teacher model (27M parameters)		0.69
Student model (from scratch) (100k parameters)		0.69
Distillation (100k parameters)	Black-Box	0.73 (+5.8%)
	Feature	0.72 (+4.3%)



Results

Test dataset (MADOS) – Pruning scores





3/ Conclusion



Conclusion

Performance:

- PascalVOC: **0.19 → 0.26** F1-score
(teacher: 0.76) using distillation.
Very sensitive to pruning.
- Airplanes DB: **0.76 → 0.82** F1-score
(teacher: 0.85) using feature distillation.
- MADOS: Marginal improvement using distillation.
Robust to pruning → up to **40%** size reduction w/o loss!

Culprits:

- Quality of the dataset (number of objects present, class diversity,...)
- GPU time consumption

Conclusions:

- Norm-based and Taylor approximation performed best for pruning
- Distillation helps for complex datasets
- The model complexity matters

What next?

Pruning-aware distillation
Autodistillation
Quantization
Test on more datasets
Bounding-box object detection



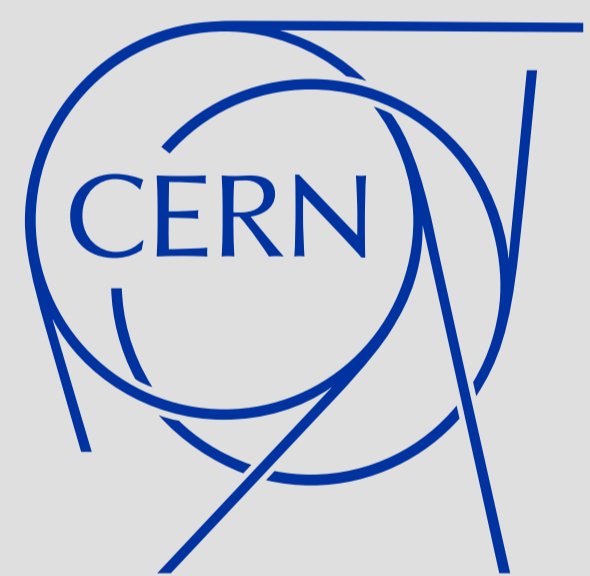
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National
Technical
University
of Athens

Simon Vellas



AGENIUM
SPACE

Thank you!

1, avenue de l'Europe
31400 TOULOUSE
France

sales.space@agenium.com

+33-646-786-334

nicolas-marcel.lemoine@agenium.com

(Technical Questions)
