AUTONOMOUS DRIVING PROPELLED BY DEEP LEARNING TECHNIQUES

Real-Time 3D Objects Detection and Segmentation based on Automotive LiDAR Technology

AUTHORS

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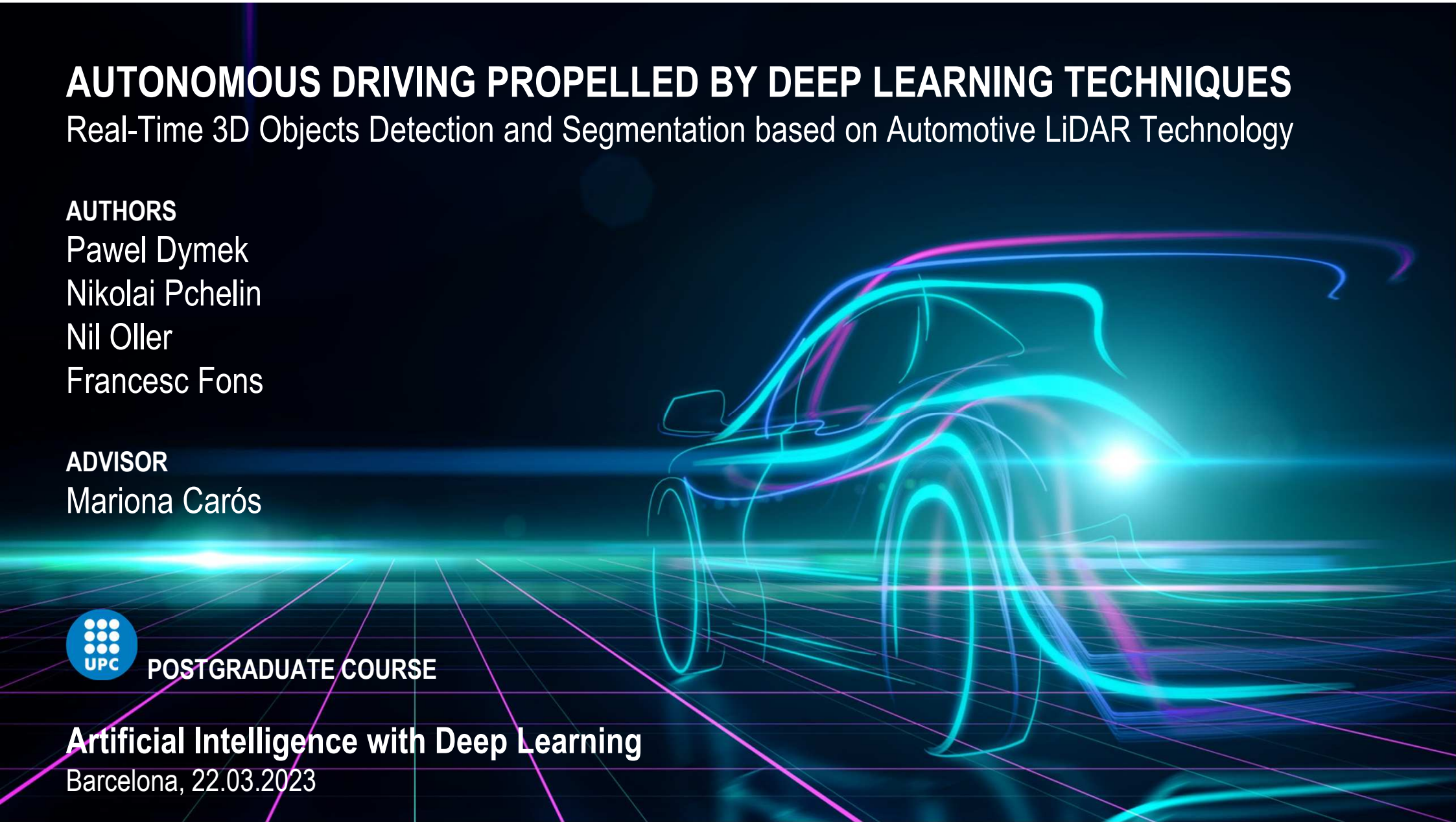

POSTGRADUATE COURSE

Artificial Intelligence with Deep Learning

Barcelona, 22.03.2023

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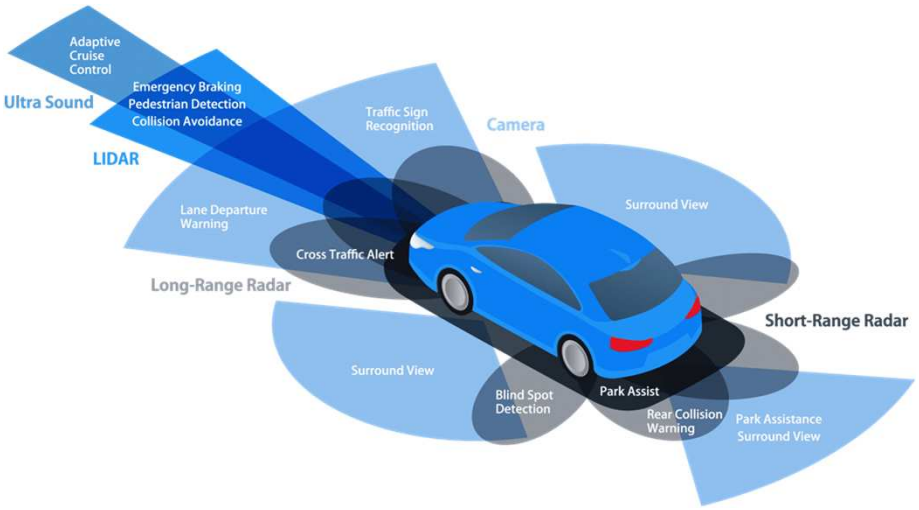
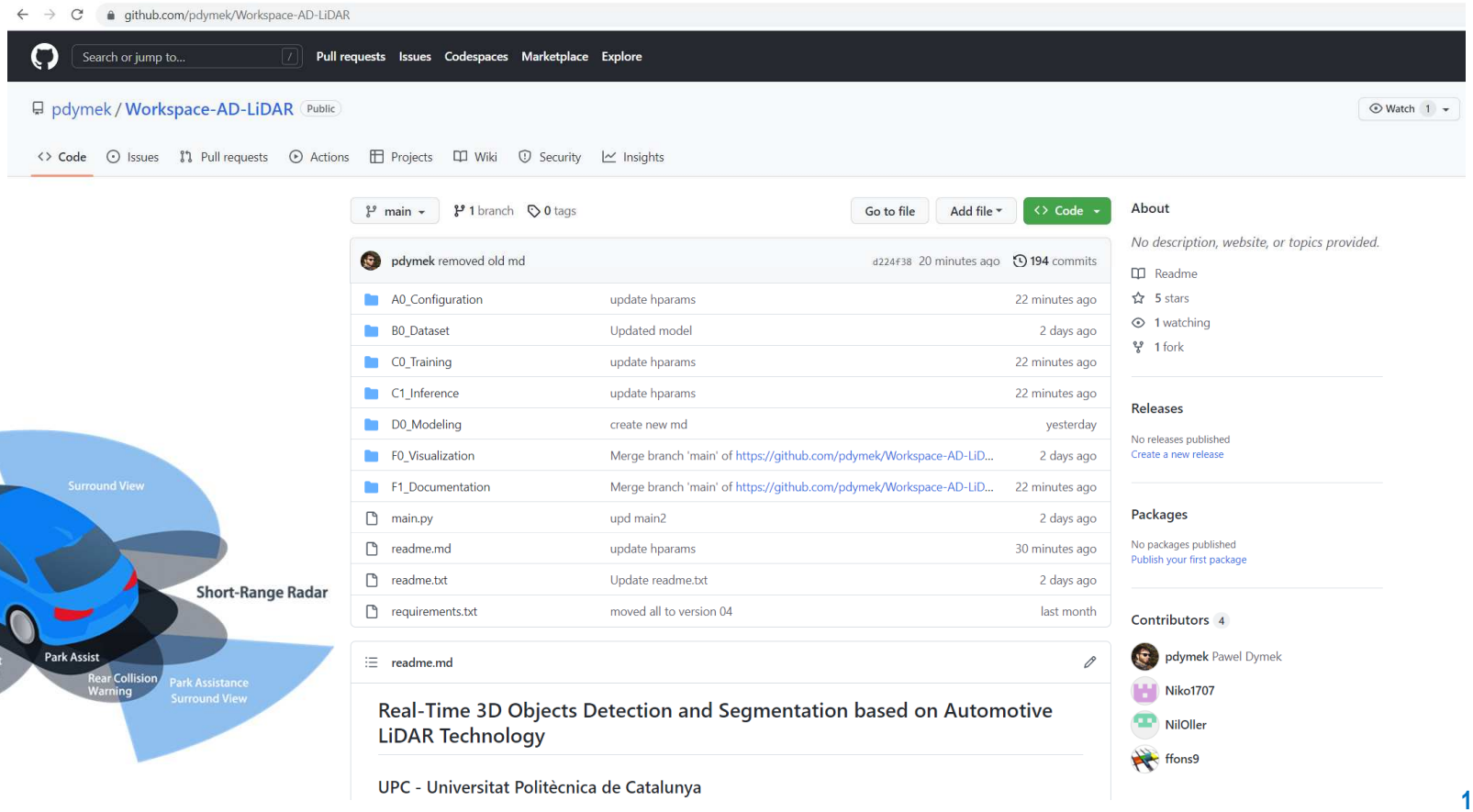
https://github.com/pdymek/Workspace-AD-LiDAR





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1. MOTIVATION
2. GOAL
3. SETUP
4. PROJECT PLAN
5. DESIGN & DEVELOPMENT
6. EXPERIMENTAL RESULTS
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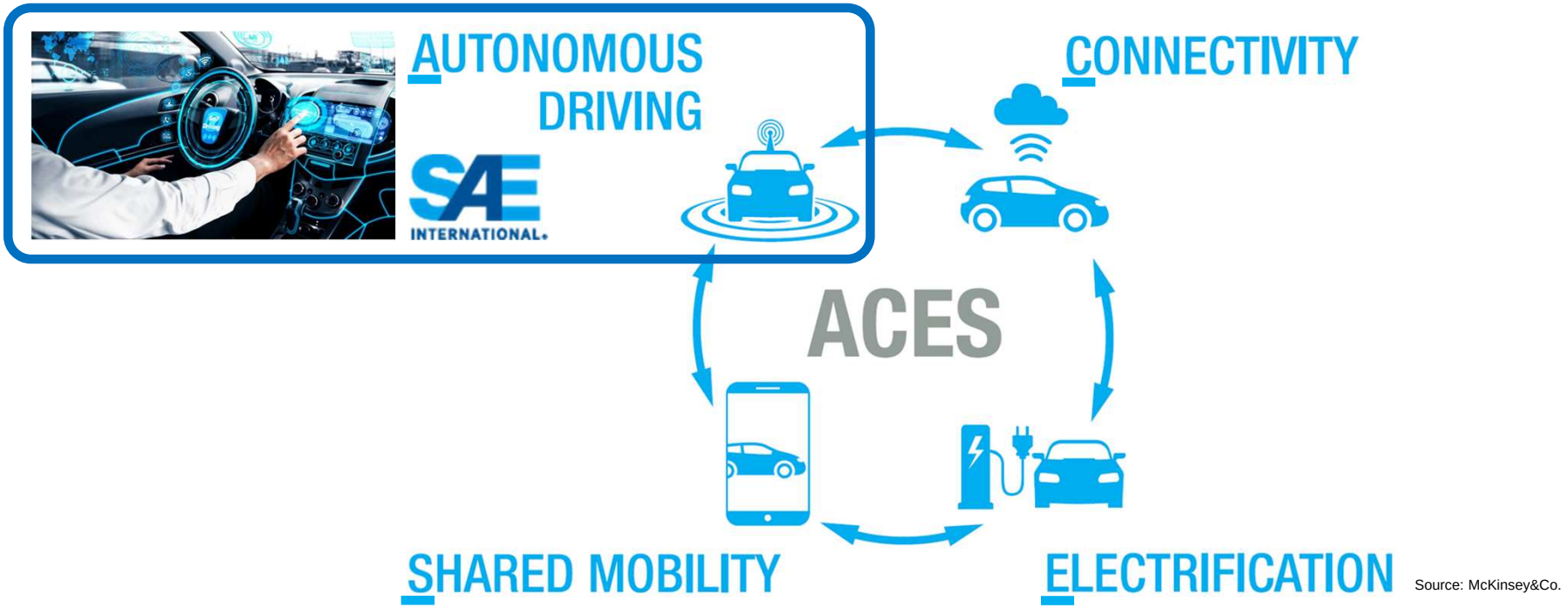
1. MOTIVATION: AUTOMOTIVE INDUSTRY – THE NEW ERA OF MOBILITY

The automotive industry, in big momentum these days, is in the middle of a revolutionary transformation towards the Software Defined Vehicle (SDV). The pace of technological innovation is accelerating at an unprecedented rate by the coexistence of **four megatrends**:



Source: McKinsey&Co.

1. MOTIVATION: AUTOMOTIVE INDUSTRY – THE NEW ERA OF MOBILITY

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SAE J3016 defines up to five different levels of automation: from assisted (feet off) to autonomous (driver off).
The more autonomy, the more sensors (e.g. RADAR, LiDAR, etc.) required to perceive the driving environment/context.

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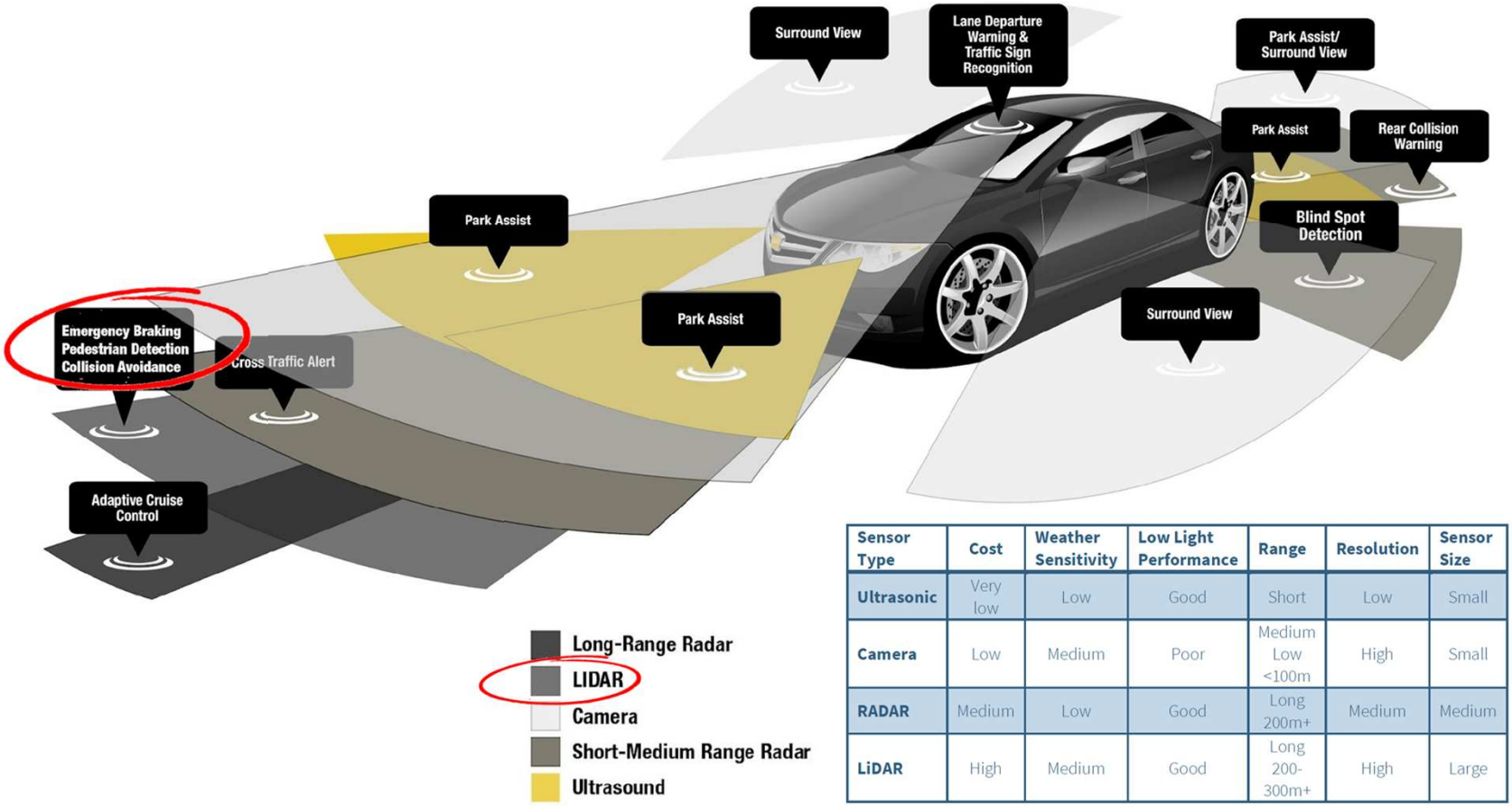
2. GOAL: AUTOMOTIVE AUTONOMOUS DRIVING OBJECTS SEGMENTATION

The objective of the project is to implement a image/video segmentation solution based on LiDAR point cloud data targeting to be embedded in an automotive electronic control unit to support AD/ADAS applications.

AD/ADAS Features

- Traffic Sign Recognition
- Emergency Braking
- Pedestrian Detection
- Collision Avoidance
- Highway Pilot



Sensor Type	Cost	Weather Sensitivity	Low Light Performance	Range	Resolution	Sensor Size
Ultrasonic	Very low	Low	Good	Short	Low	Small
Camera	Low	Medium	Poor	Medium Low <100m	High	Small
RADAR	Medium	Low	Good	Long 200m+	Medium	Medium
LiDAR	High	Medium	Good	Long 200-300m+	High	Large

Source: Strategy Analytics

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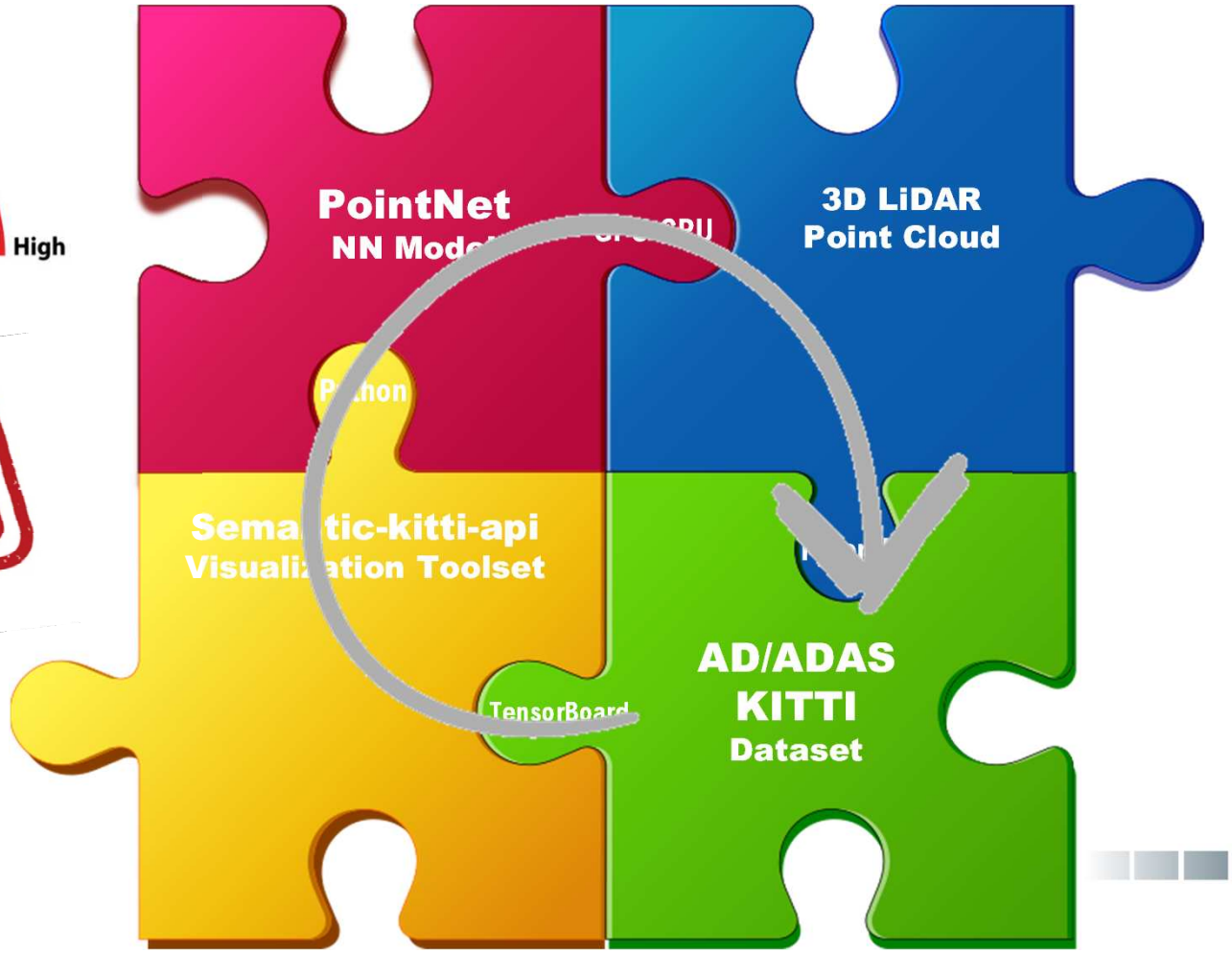
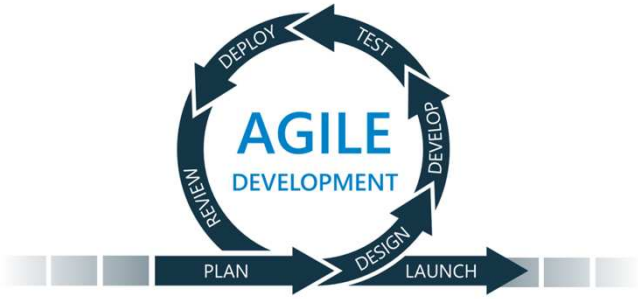
3. SETUP: INTEGRATION OF TECHNOLOGIES – OUR BIGGEST CHALLENGE !

Connecting the dots…

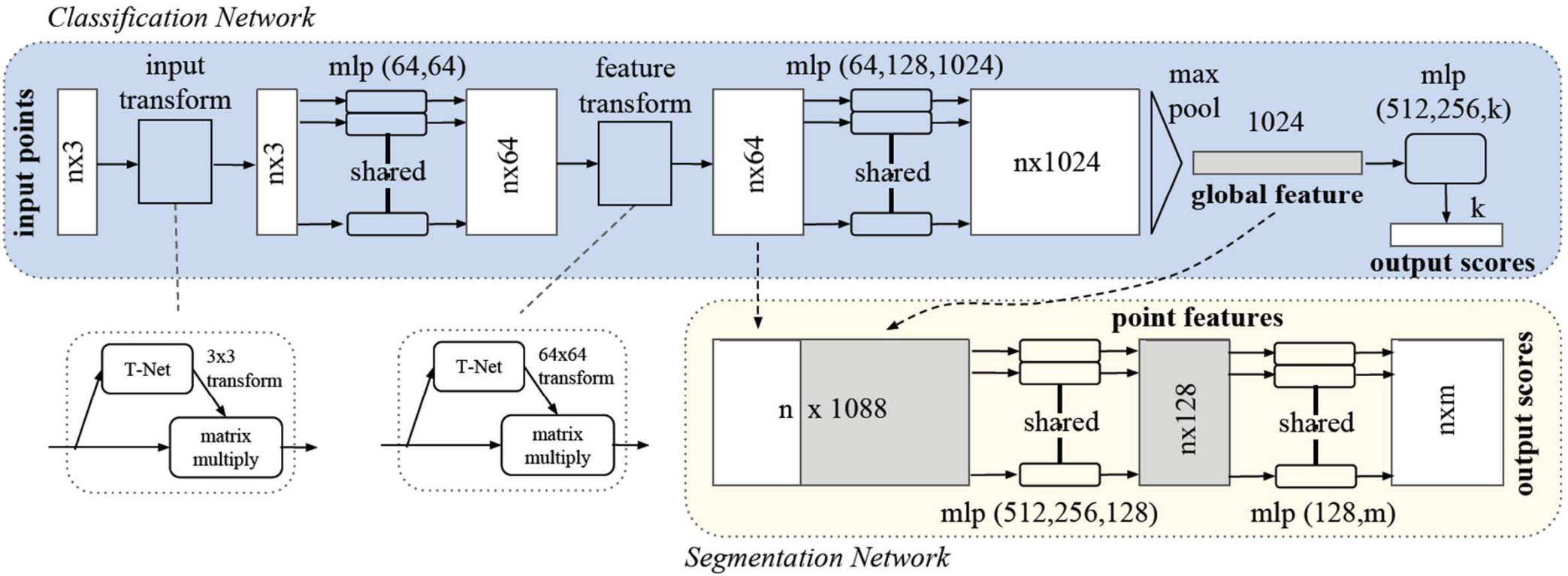




3. SETUP (1oo4): NEURAL NETWORK POINTNET MODEL

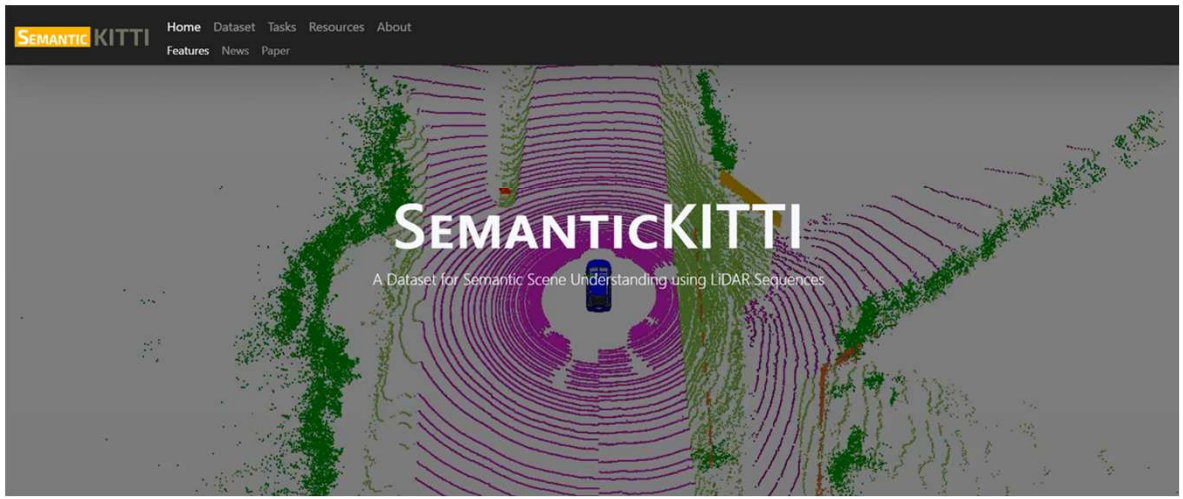
PointNet is one of the most well-know NN models for classification and segmentation based on point cloud.

Architecture



3. SETUP (2oo4): KITTI/SEMANTICKITTI DATASET

KITTI/SemanticKITTI is probably the most used dataset in autonomous driving research.



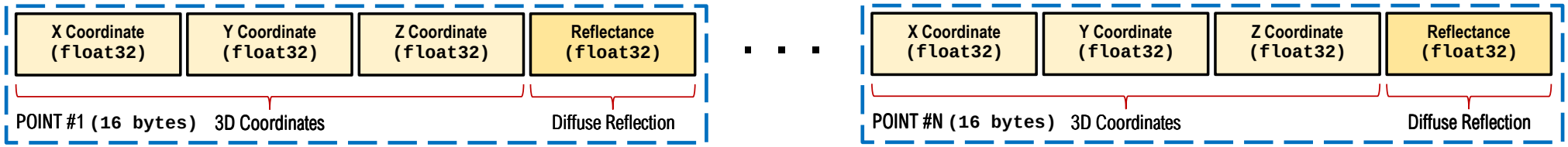
3. SETUP (3oo4): 3D POINT CLOUD LIDAR SENSOR

Velodyne Lidar
AN OUSTER COMPANY

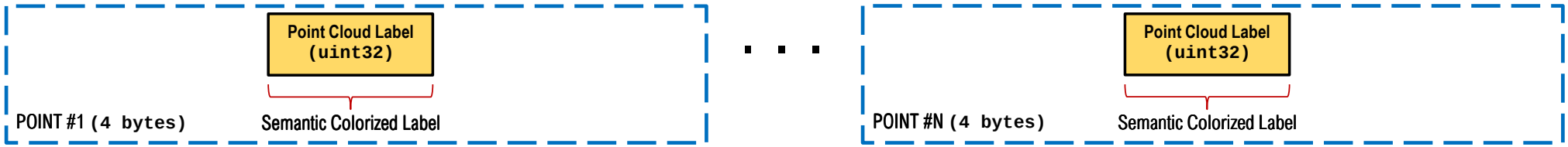
Technical Characteristics

- Velodyne HDL-64E LiDAR sensor
- Point cloud raw data captured at 10 Hz
- Around 120K points per frame

POINT CLOUD DATA FORMAT (.bin file)

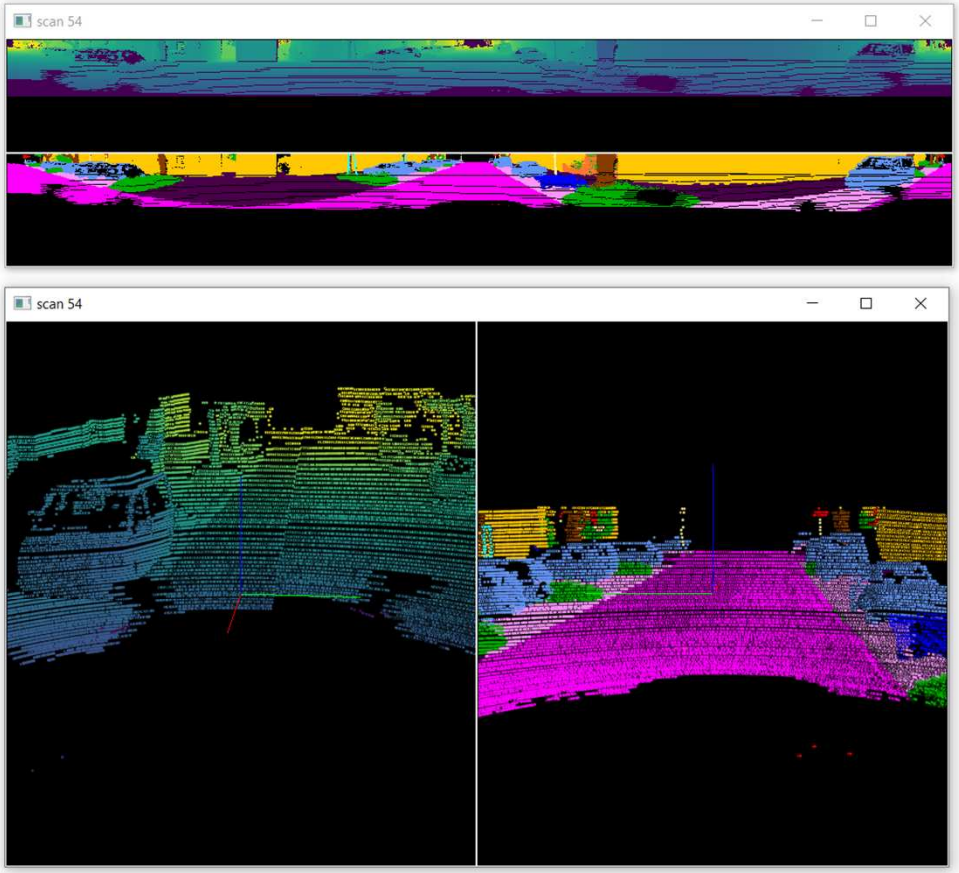


LABEL & PREDICTION DATA FORMAT (.label file)

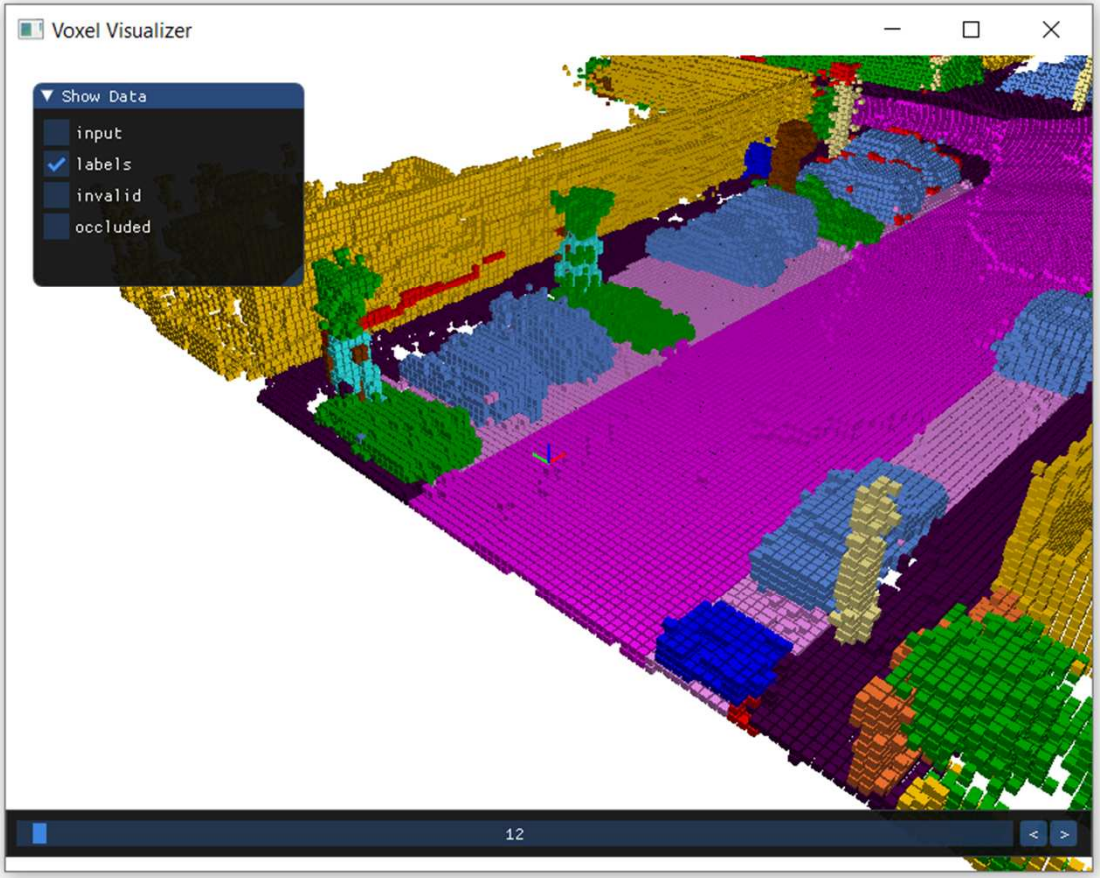


3. SETUP (4oo4): 3D POINT CLOUD VISUALIZATION

semantic-kitti-api toolset



Point Cloud View



Voxels View

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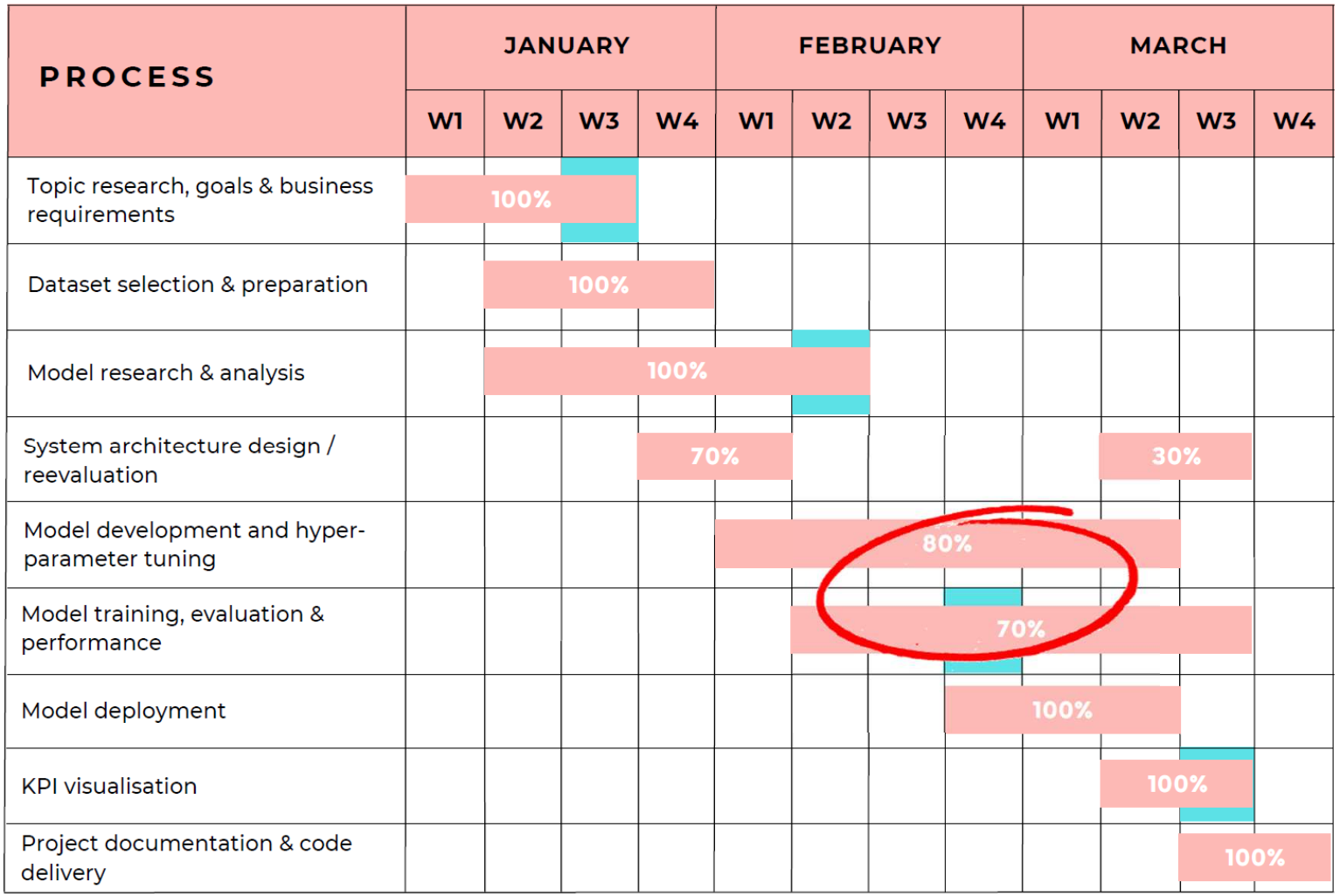
4. PROJECT PLAN – MILESTONES & ACHIEVEMENTS

Our journey…



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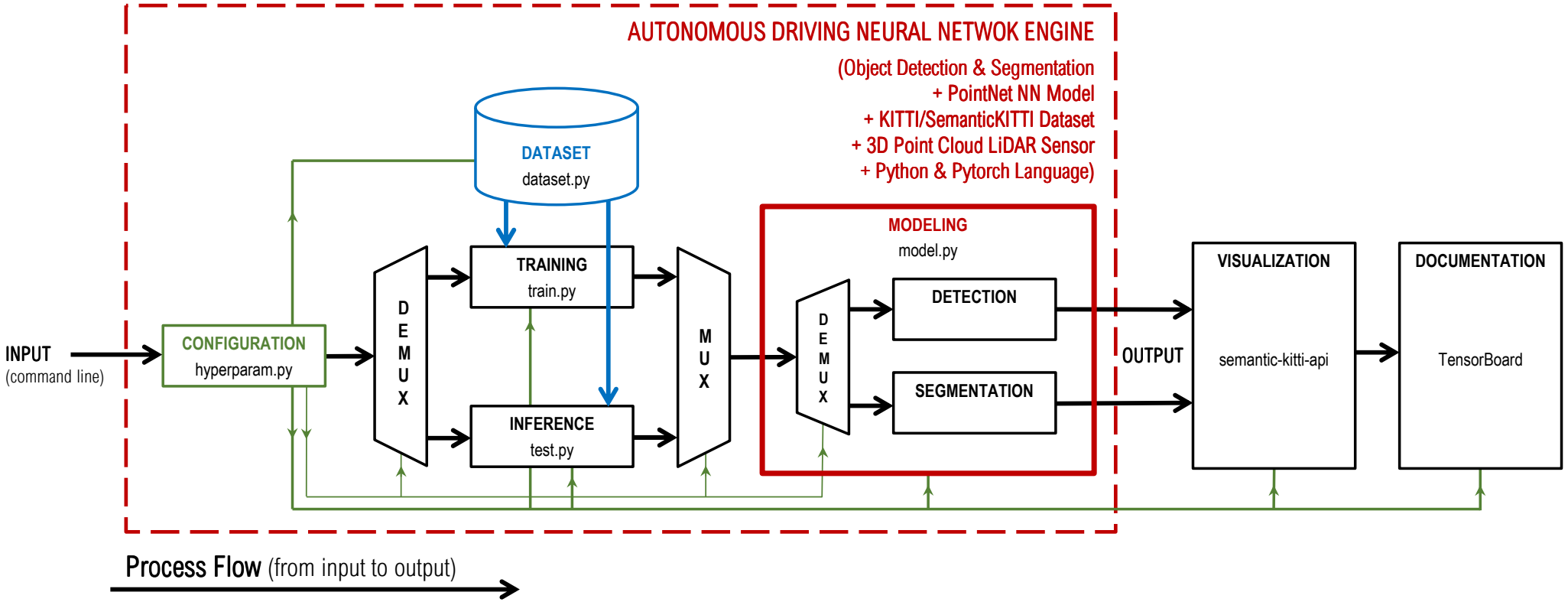
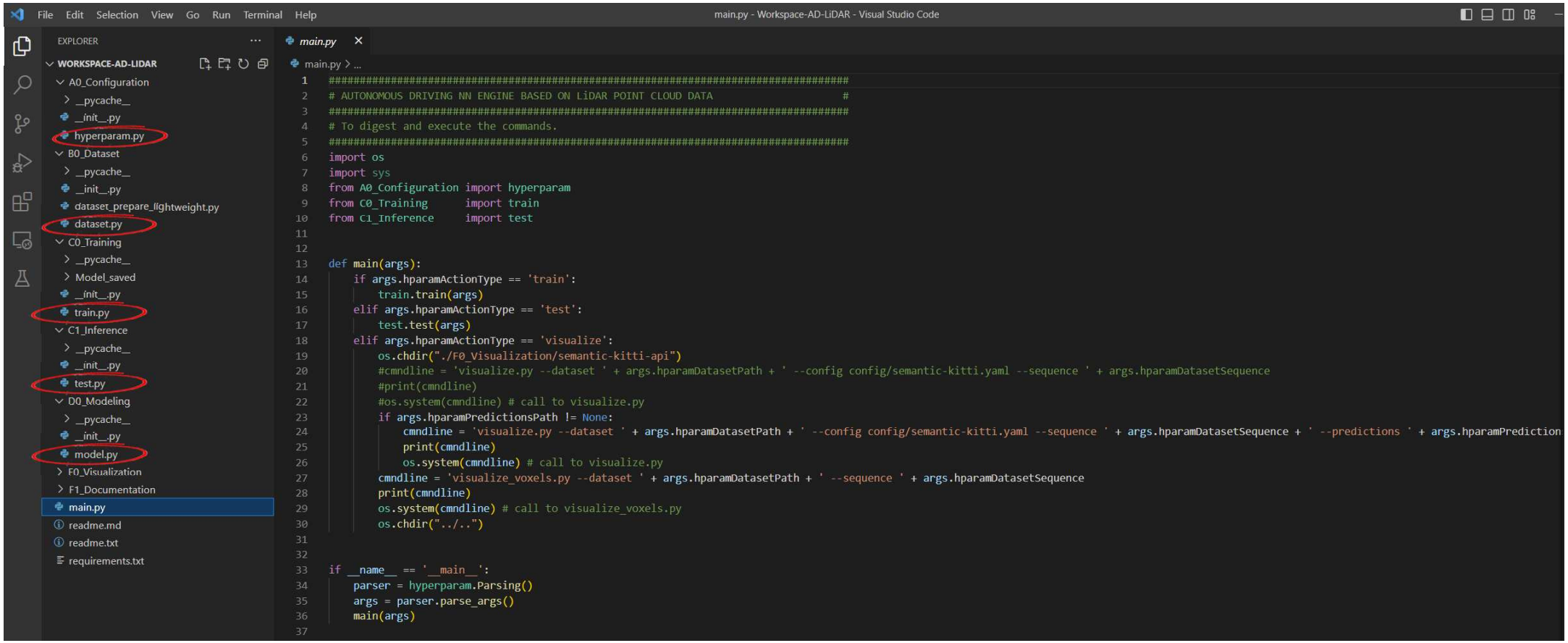
5. DESIGN & DEVELOPMENT (1oo4): SYSTEM ARCHITECTURE

Modular, flexible and scalable NN concept by design.



5. DESIGN & DEVELOPMENT (2oo4): SOFTWARE IMPLEMENTATION

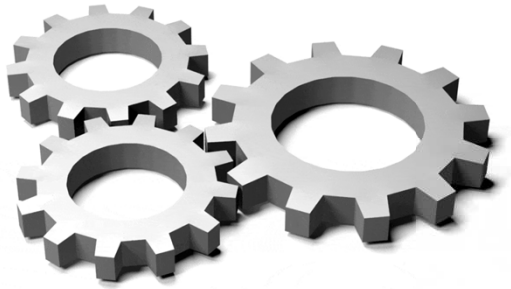
The core technology developed is embedded in five key files addressing configuration, data handling, modeling, training and test.



5. DESIGN & DEVELOPMENT (3oo4): FROM TRAINING TO INFERENCE

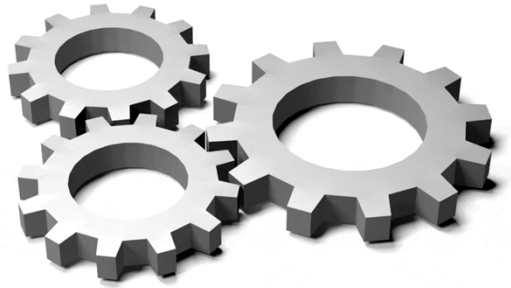
The resultant trained model is saved as a **.pth file** to right after be used in the inference.

TRAINING & VALIDATION



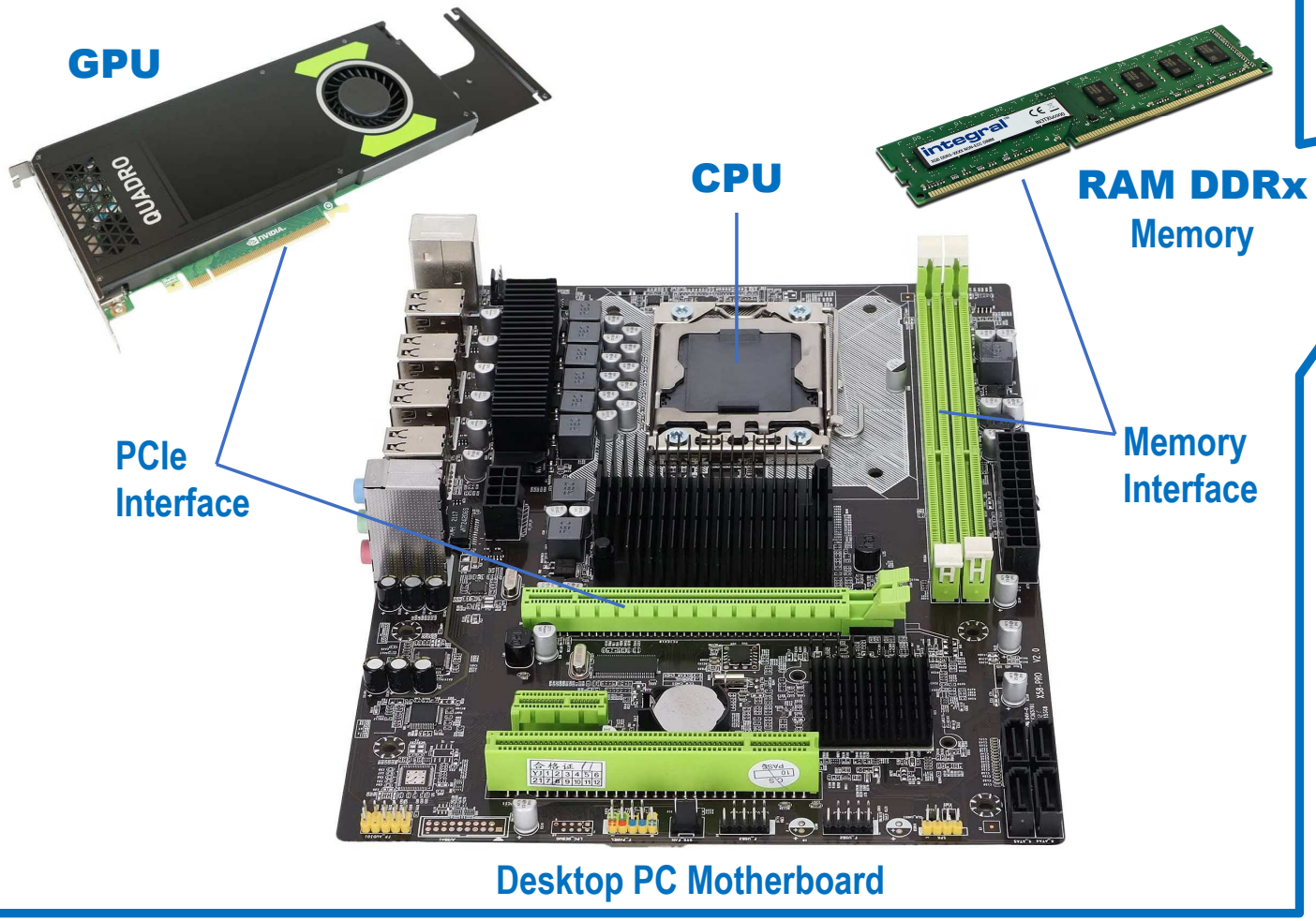
.pth file (PointNet weights & biases)

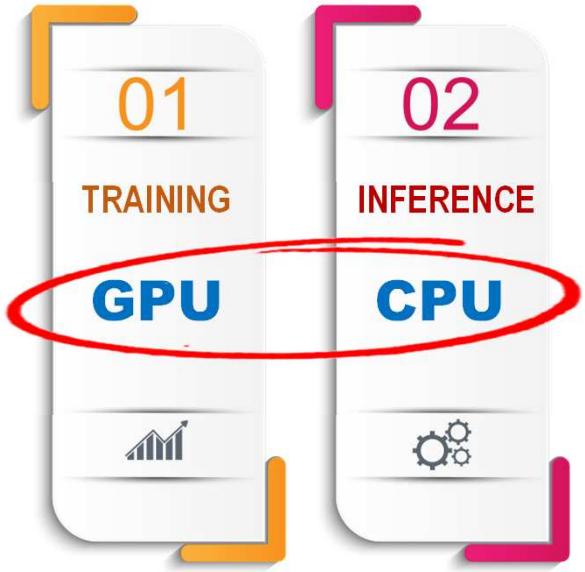
TEST (INFERENCE)



5. DESIGN & DEVELOPMENT (4oo4): HARDWARE PLATFORM

Three key components: CPU, GPU and RAM.





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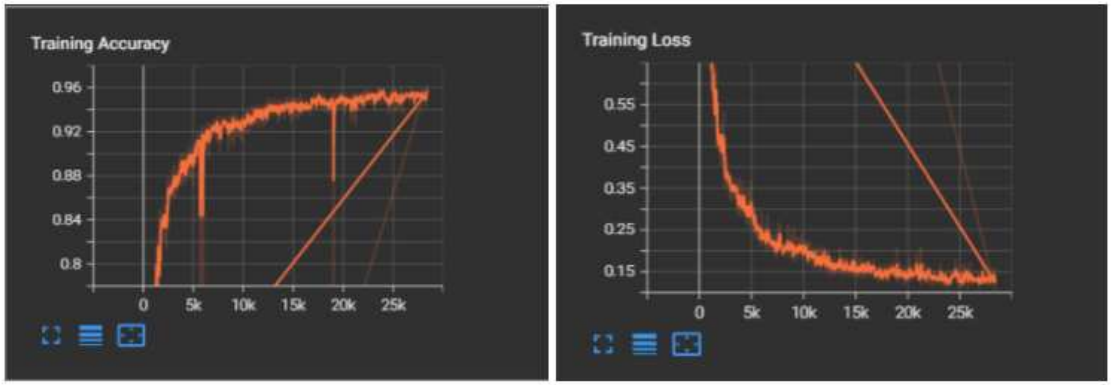
6. EXPERIMENTAL RESULTS (1oo3)

Visual analysis and assessment of results supported by the **TensorBoard** tool.

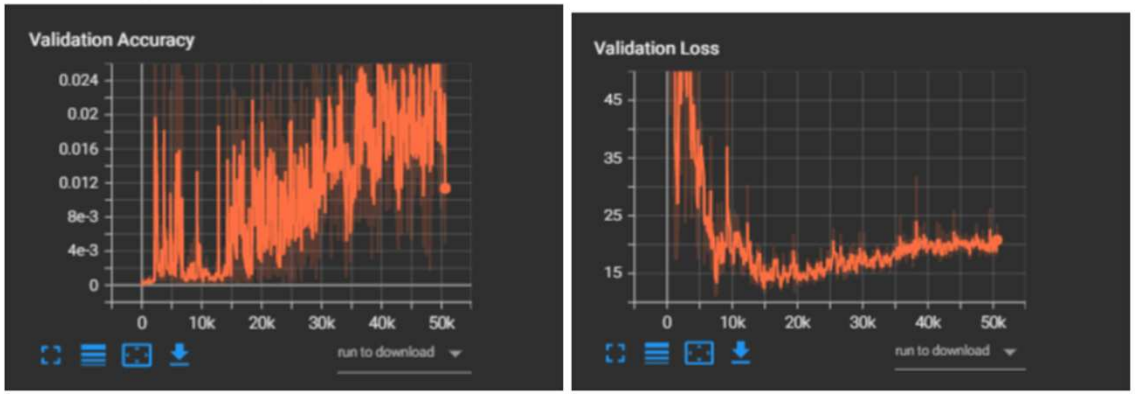
lr = 0.001 (Best model in epoch7)
After that the model is overfitting.

Training (Seq_00)



lr = 0.01 (Best model epoch 0)
Lw_version of Seq_00

Validation(Seq_08)



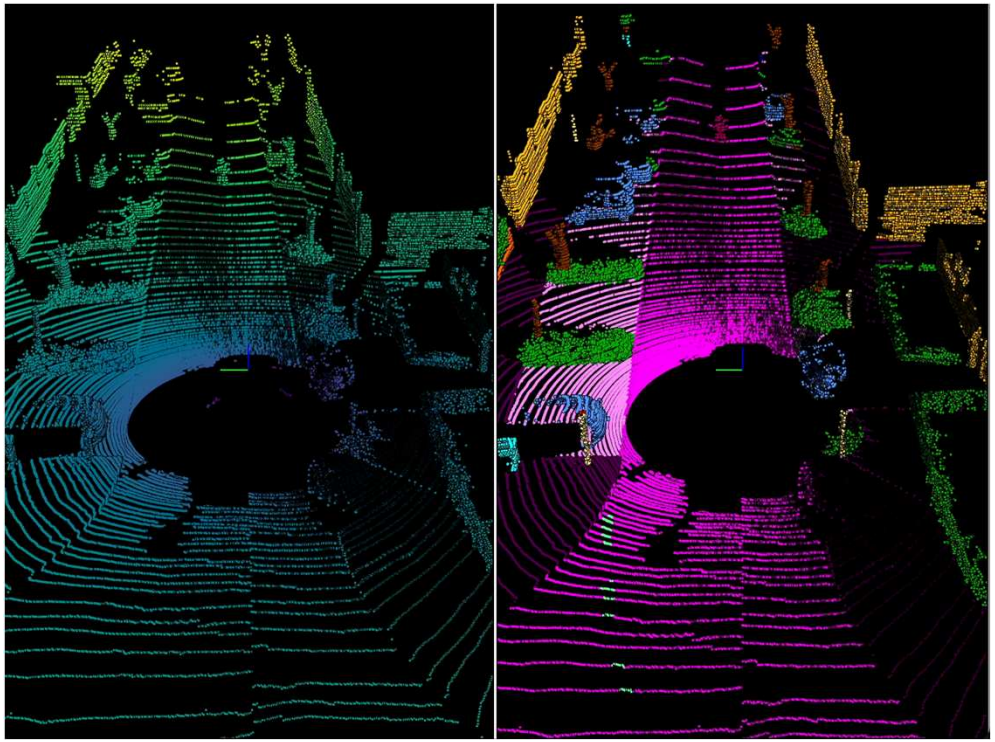
6. EXPERIMENTAL RESULTS (2oo3)

Visual analysis and assessment of results supported by the **TensorBoard** tool.

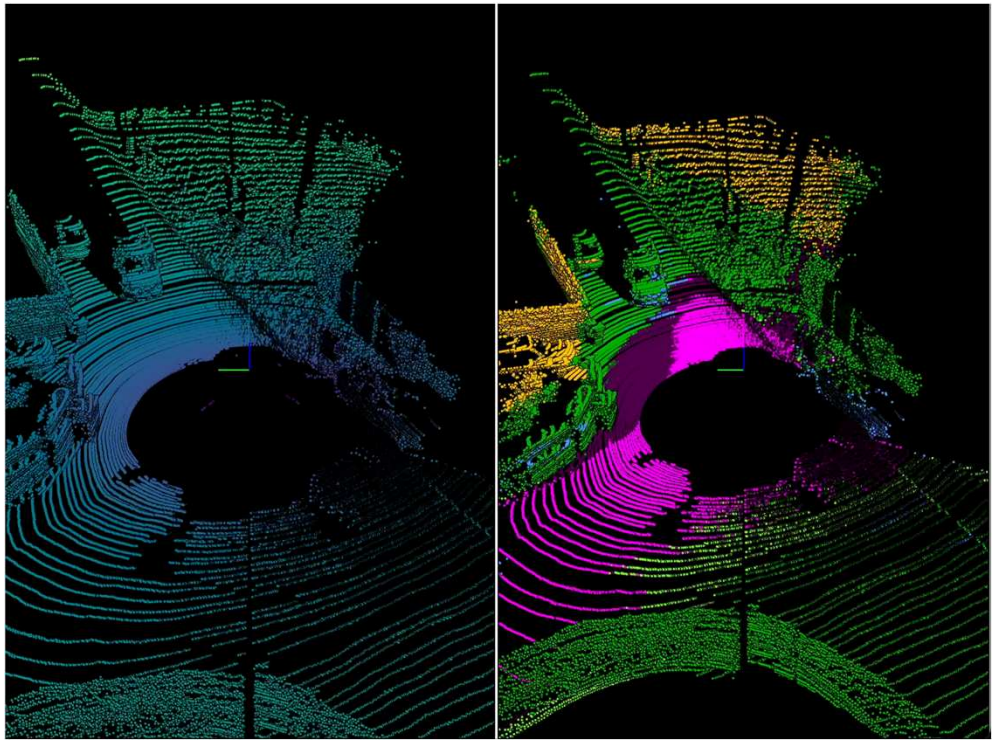
Time for Training (RTX 3060)	Sequence for Training	Sequence for Validation	lr	Accuracy	mIoU
~5h	Seq_00	Seq_08	0.001	0.35	-
~3h	(few Categories) Seq_00	Seq_08	0.001	4.5e-4	-
~2h	(few Categories) Seq_00	(few Categories) Seq_08	0.01	0.46	0.88304
~2h	(few Categories) Seq_00	(few Categories) Seq_08	0.001	0.43	0.87869

6. EXPERIMENTAL RESULTS (3oo3)

Visualization of results in real-time through **semantic-kitti-api** tool.



Ground Truth (Labeled Data)



Prediction (Inference)

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7. CONCLUSIONS

- Relevant AD/ADAS use case (pain point) explored. Business case with high impact in the automotive industry.
- The integration of different technologies was the main challenge of the project.
- Learning by doing. Gaining and absorbing knowledge quickly was our main strength.
- Our “time-aggressive” development flow: Python program (instead of Colab) and PC with CPU/GPU (instead of cloud).
- Lesson learned: to balance your AI/DL workload (batch sizes, etc.) with the RAM, CPU and GPU of your platform
- It is crucial to iterate many times your solution in order to achieve good results.
- Excellent teamwork of the four team members following agile methodologies.

- Although the start of the project was quite tough, the job was done and delivered on time!

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Neural Network:

- https://github.com/marionacaros/3D-object-segmentation-light-PointNet
- https://github.com/Yvanali/KITTISeg
- https://github.com/fxia22/pointnet.pytorch

Point Cloud Visualization Tool:

- https://github.com/PRBonn/semantic-kitti-api

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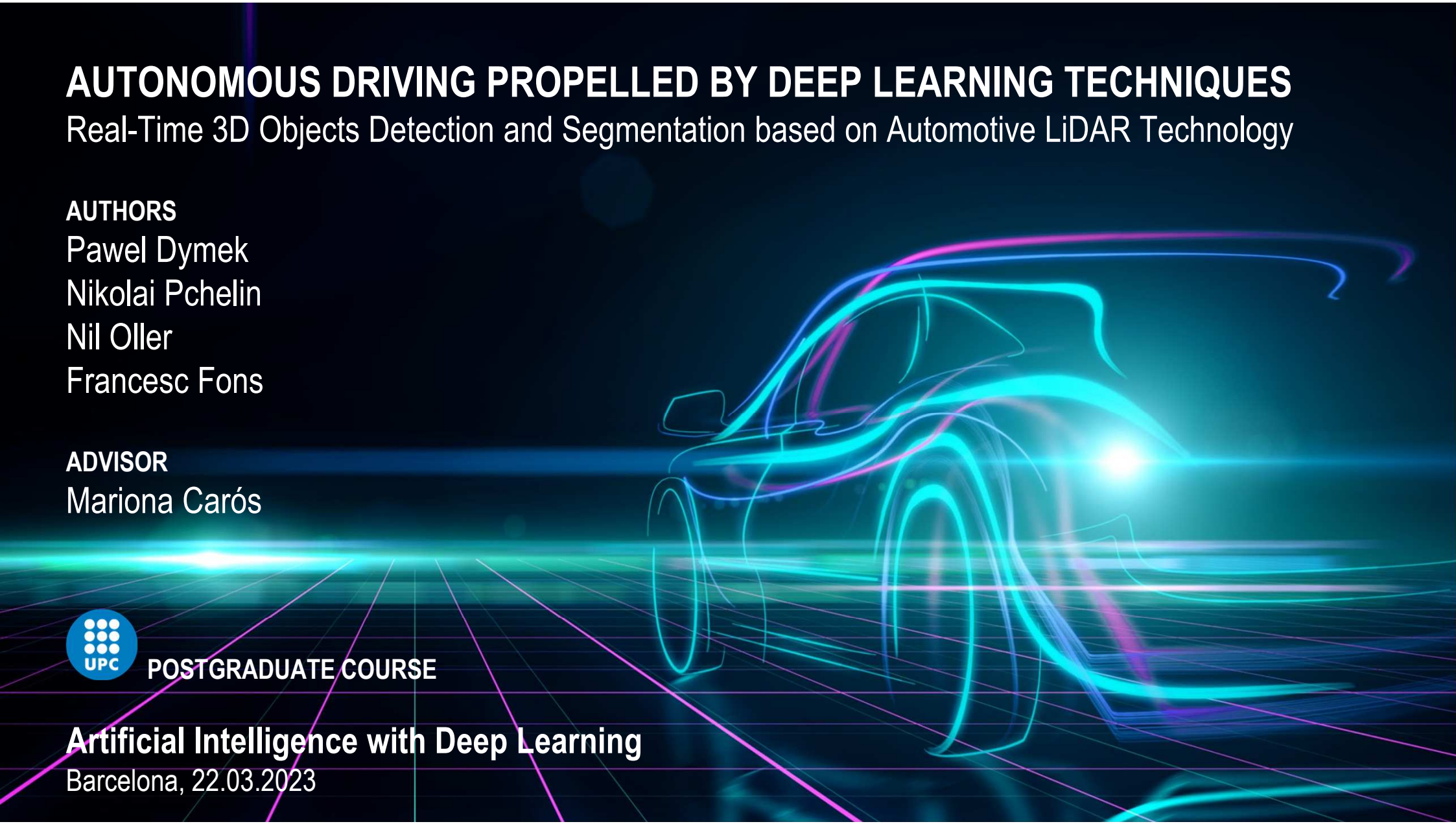

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