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Enhancing Autonomous Train Safety Through A Priori-Map Based Perception

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Outline

Context
- Autonomous train project
- Concept
- Combining map and perception concepts

AI implementation
- Related works for the AI task
- Railway pointcloud dataset
- Deep learning model : KP-FCNN
- 3D railway segmentation
- Results and analysis

Work in progress

Autonomous train project

TRAIN AUTONOME SERVICE VOYAGEURS

- Autonomous Train Passenger Service project aims to develop a prototype of autonomous train GoA4 and test most of the autonomous system functions in realistic scenarios.
- This prototype is a retrofitted train with perception, communication and navigation systems on-board.
- For perception systems, the objective is to maximize performances under the hardware constraints of integrated systems.

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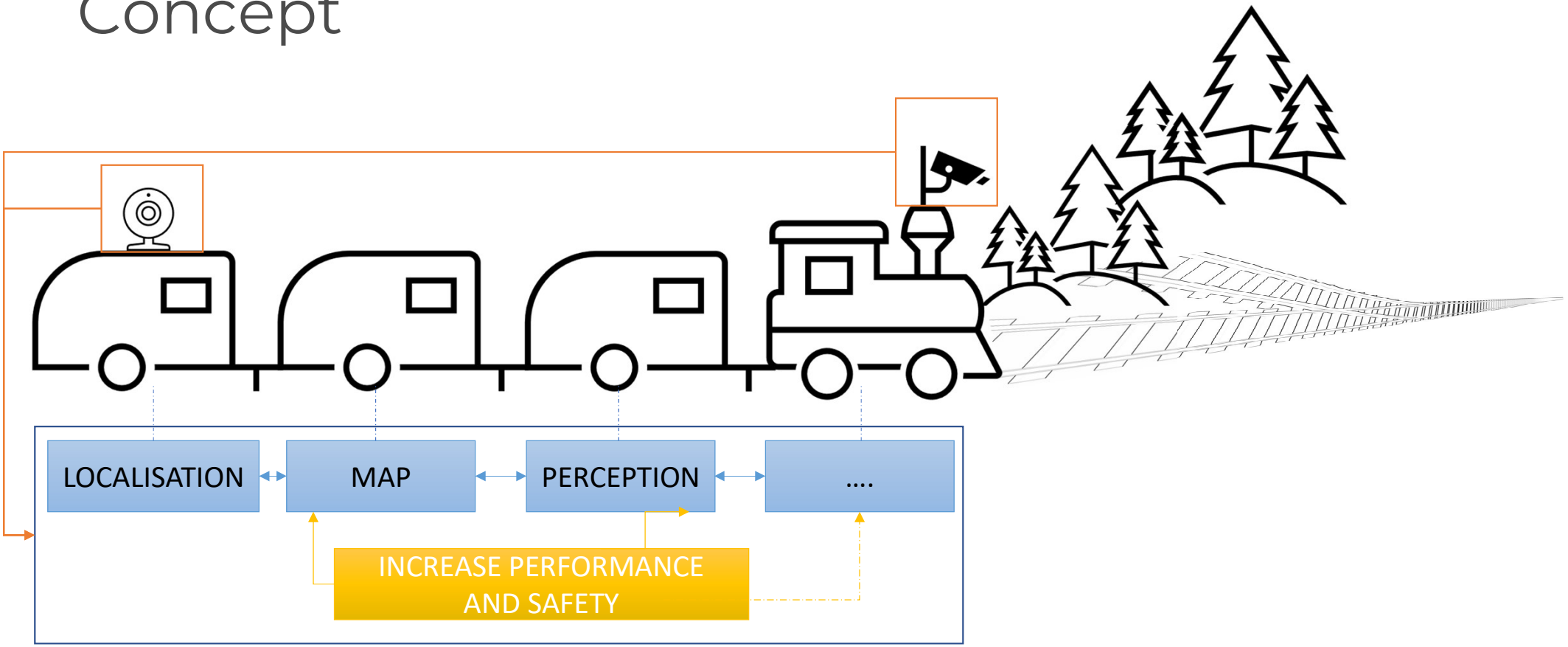
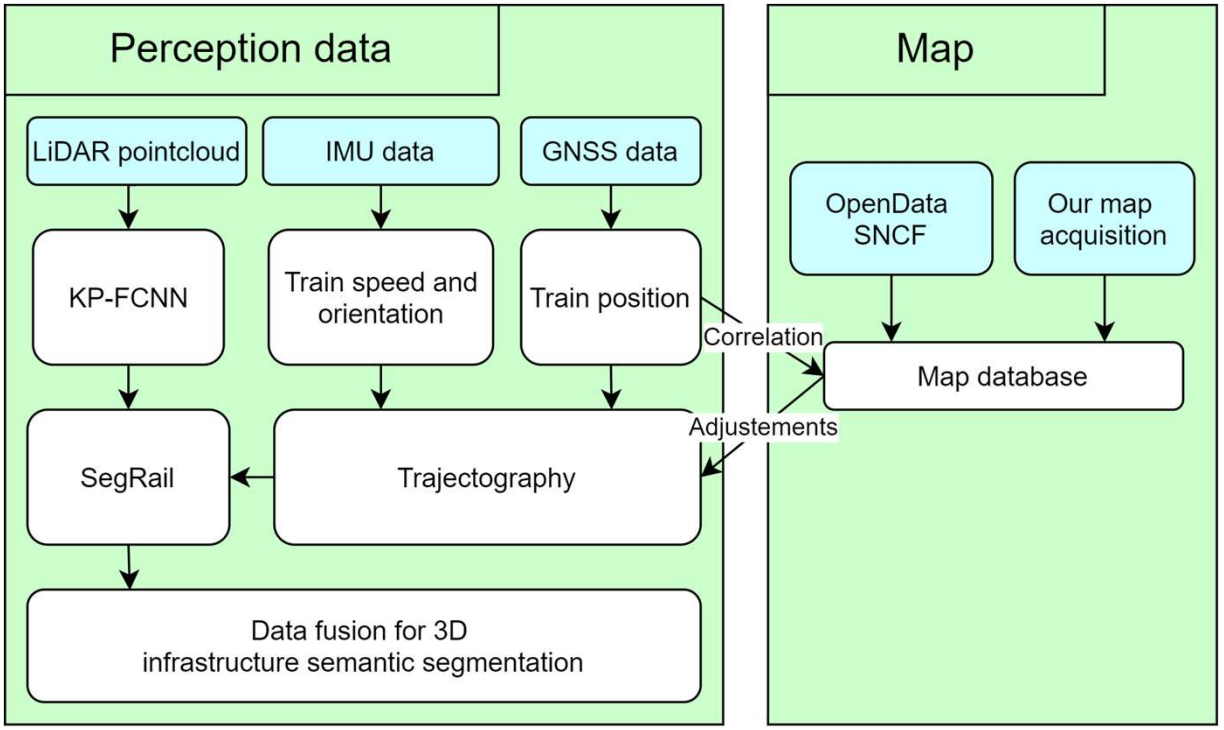
Concept



AI algorithms does not provide enough confidence to railway institutions to try them during real railway tests. **How can we improve trust in AI ?**

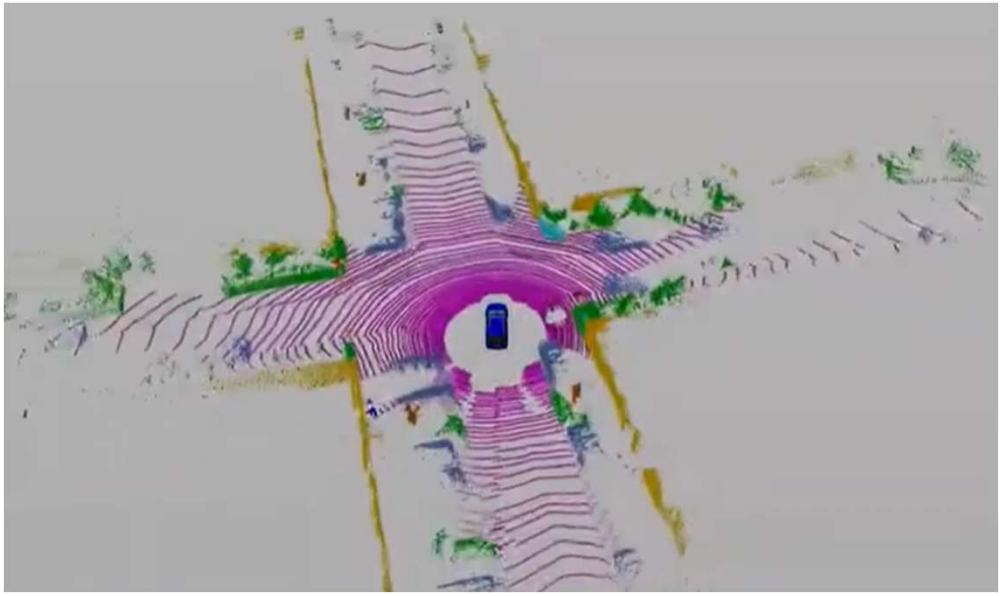
Combining map and perception concepts

Combination use of perception and map data for 3D railway infrastructure segmentation



High level data fusion may increase confidence rates in DL classification, as redundant technologies does.

Related works for the AI task



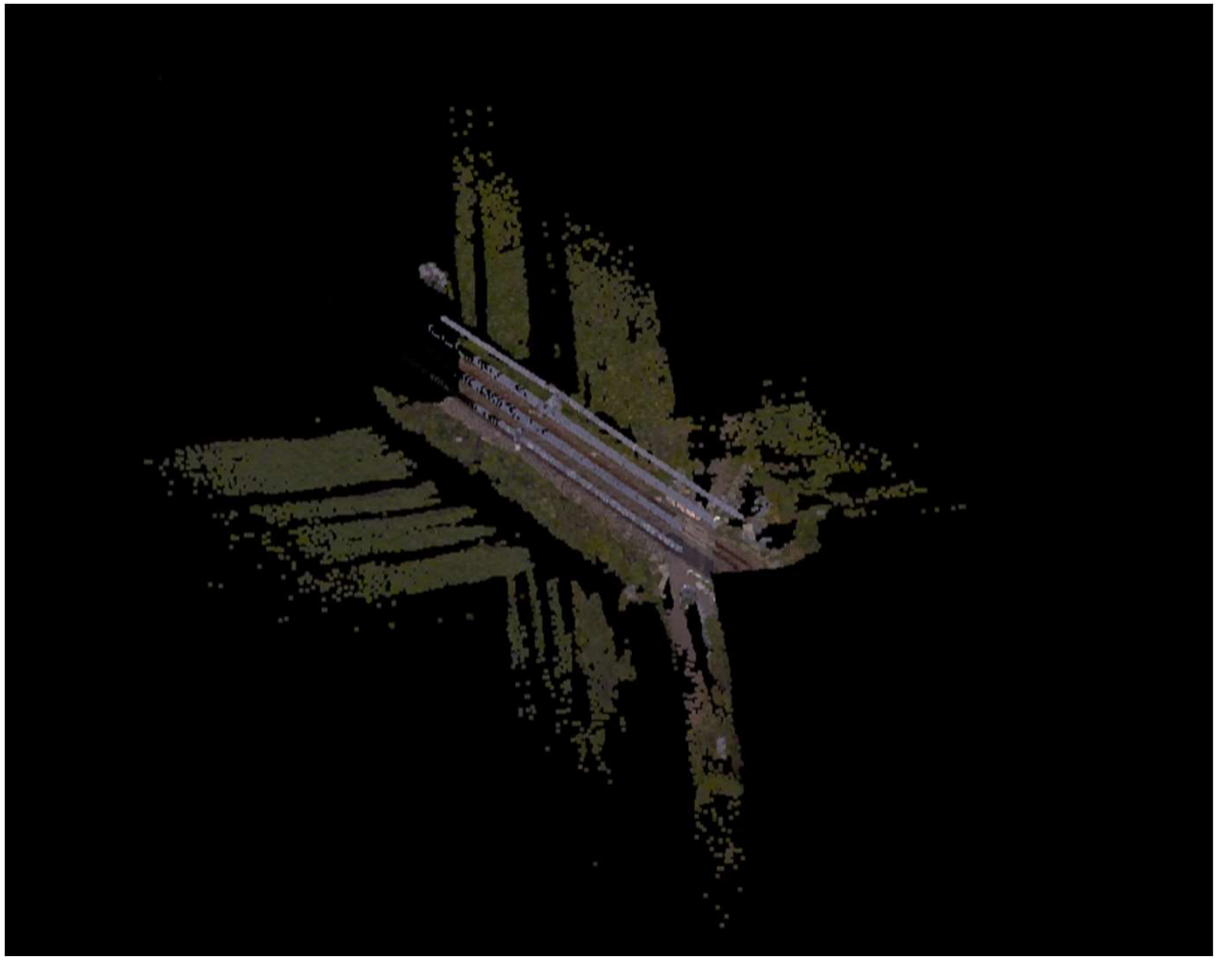
SemanticKITTI dataset [1]

Task : Semantic segmentation 3D is widely used for autonomous cars environment analysis (obstacle and signs detection).

- No railway pointcloud datasets available publicly
- Lack of use of LiDAR's sensor in railway
- Moreover, a LiDAR pointcloud contains deterministic points presenting this sensor as more accurate than a camera

[1] J. Behley, M. Garbade, A. Milioto, J. Quenzel, S. Behnke, C. Stachniss, J. Gall, SemanticKITTI: A Dataset for Semantic Scene Understanding of LiDAR Sequences, IEEE/CVF International Conference on Computer Vision (ICCV), 2019

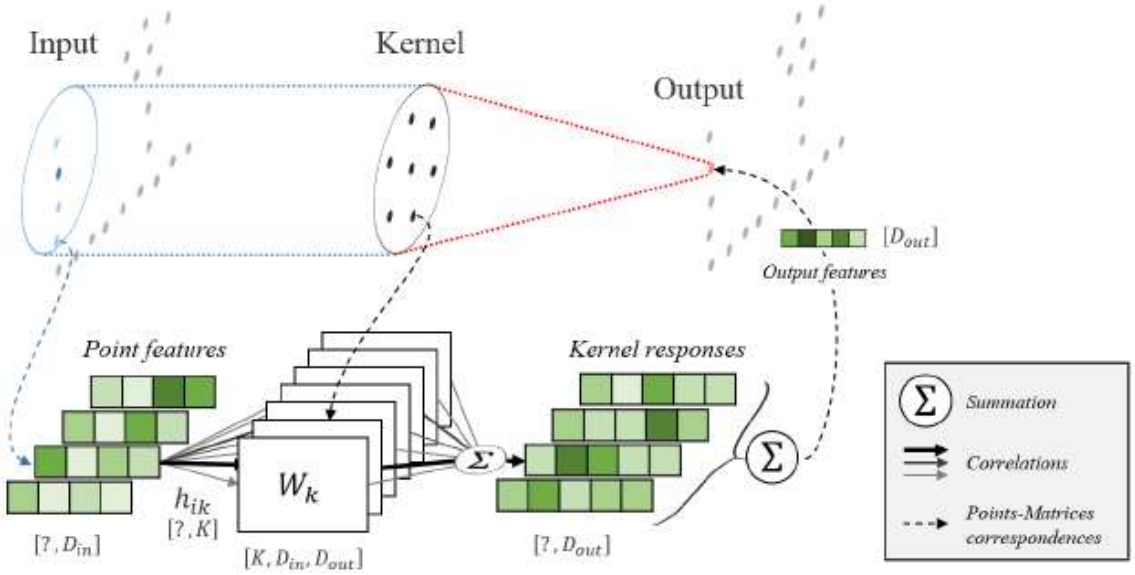
Railway pointcloud dataset



Classification of each point in a known label : railway, level crossing, catenary, vegetation, etc allows to locate and label each detected points.

We use an annotated dataset of pointclouds, trajectography, and map systems synchronized.

Deep learning model: KP-FCNN [2]



KPConv [2] stands for **Kernel-Point Convolution**.

These convolutions takes radius neighborhoods as input and processes them with weights spatially located by a small set of kernel points.

[2] H. Thomas, C. R Qi, J-E. Deschaud, B. Marcotegui, F. Goulette, L. J Guibas, Kpconv: Flexible and deformable convolution for point clouds, In Proceedings of the IEEE International Conference on Computer Vision, p. 6411–6420, 2019

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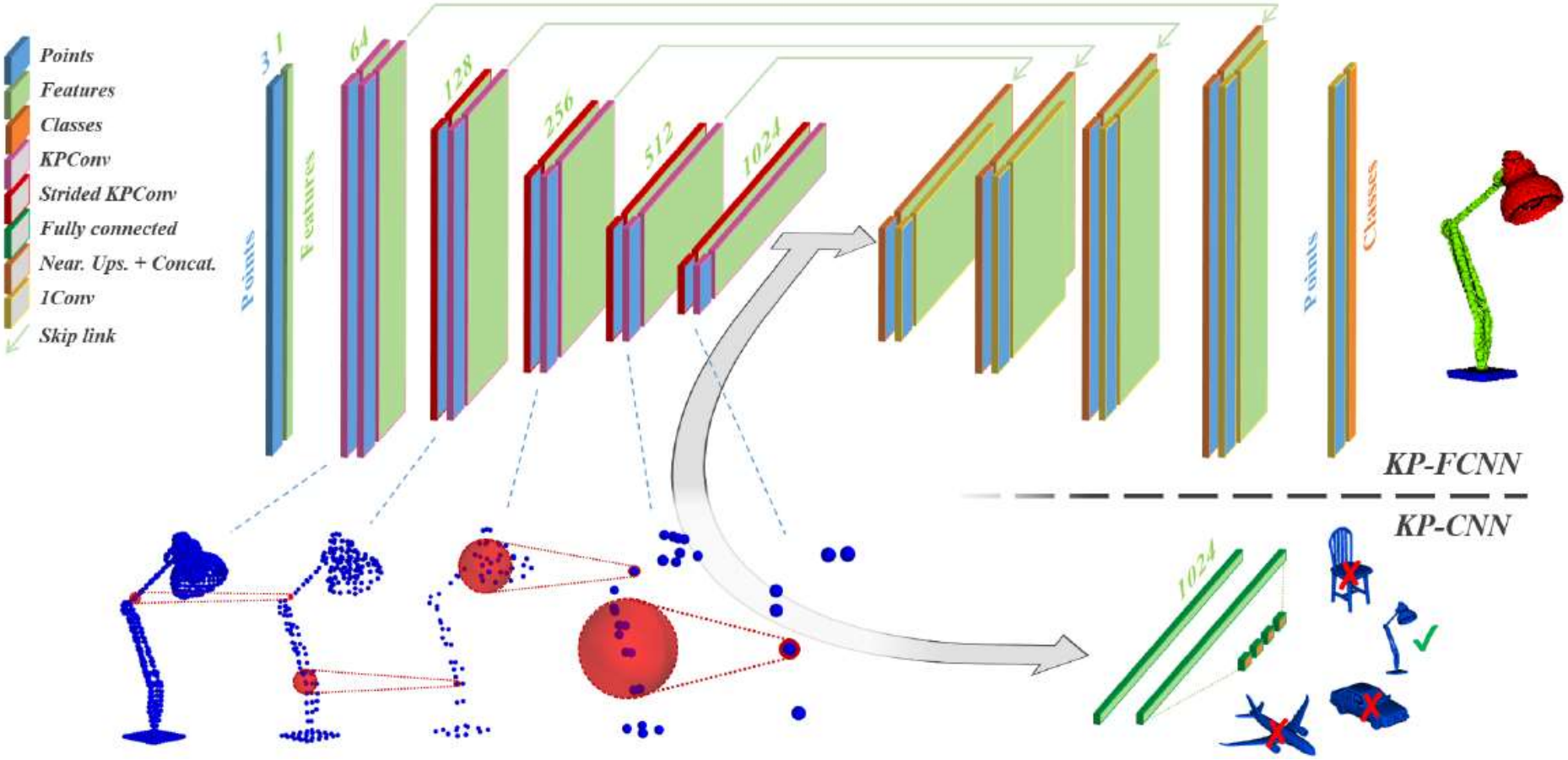
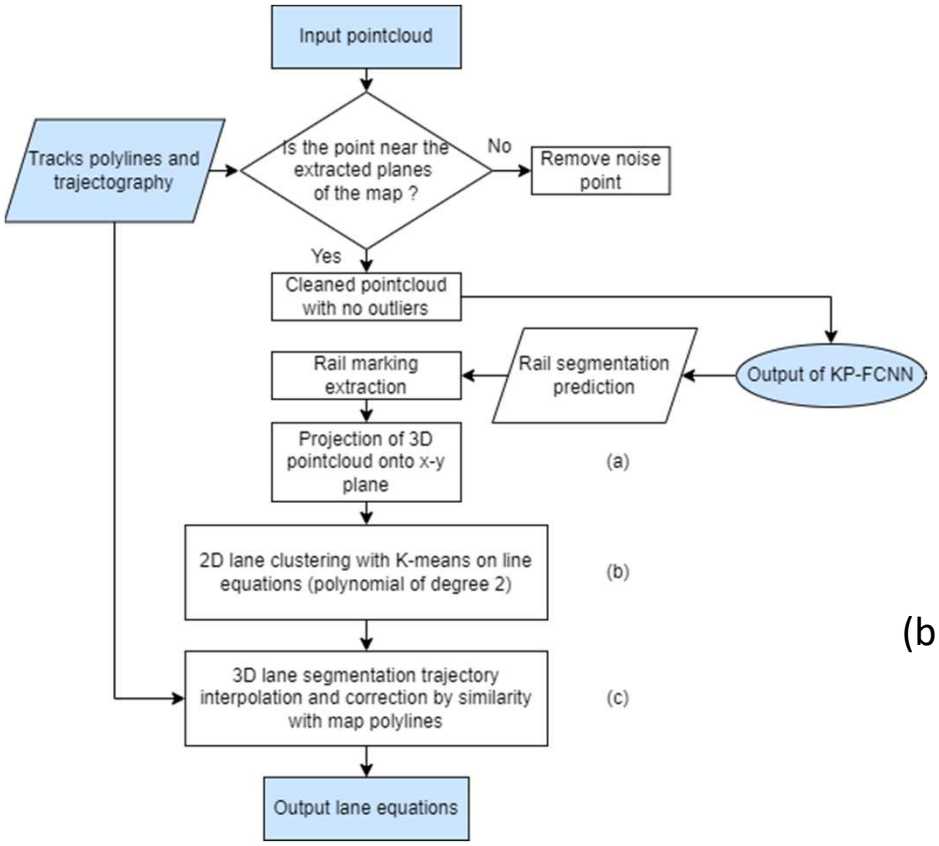
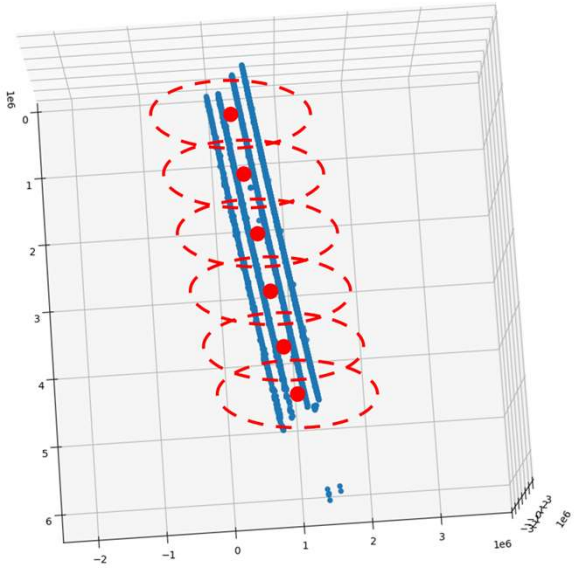


[2] H. Thomas, C. R Qi, J-E. Deschaud, B. Marcotegui, F. Goulette, L. J Guibas, Kpconv: Flexible and deformable convolution for point clouds, In Proceedings of the IEEE International Conference on Computer Vision, p. 6411–6420, 2019

3D railway segmentation



Data processing architecture based on the NN and railway norms hypothesis



(b) K-means clustering optimises local railway segmentation

All the crispy technical details are in the paper ☺

Results and analysis

Analysis 1 : Comparison of the AI performance based on usual AI metrics

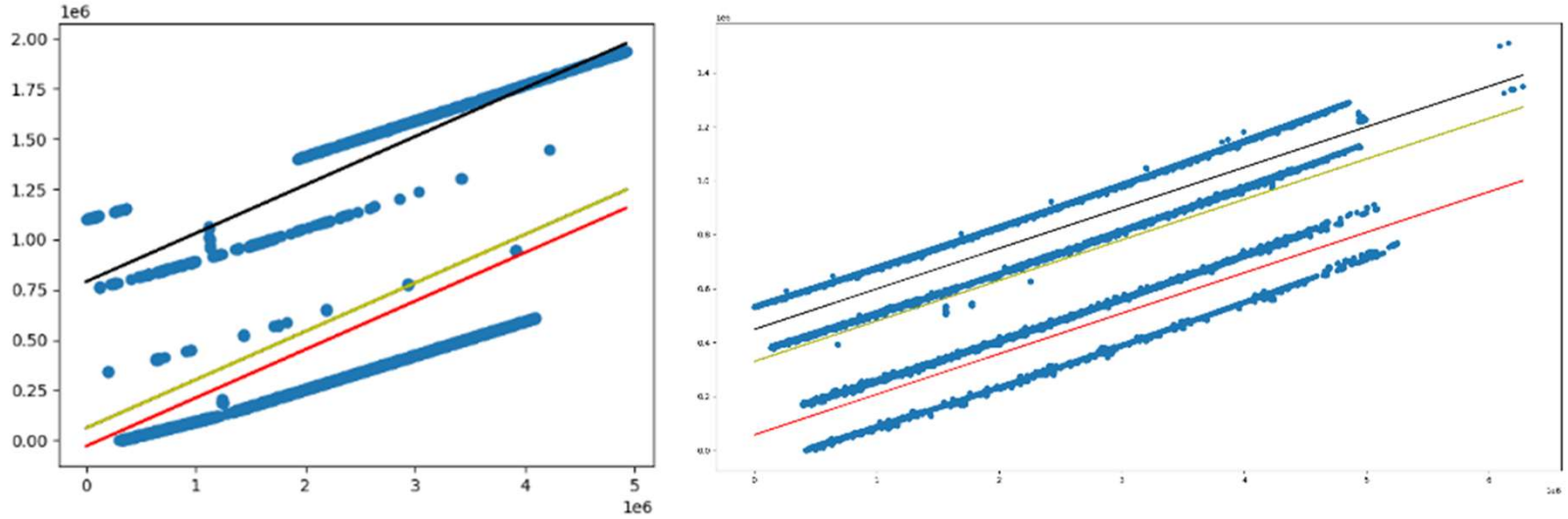
Model	Experiment	Dataset	mIoU ↑	mMink ↓	Runtime ↑
KP-FCNN	Pretrained [7] (**baseline**)	KITTI [3]	58.8 %	-	17.5
KP-FCNN	Transfer learning	Railway	46.4 %	-	14
KP-FCNN	Trained from scratch	Railway	54.3 %	35.1732	14
SegRail (base)	Preprocessed dataset	Railway	60.9 %	34.7636	20
SegRail (a)	2D projection	Railway	60.9 %	21.6333	20
SegRail (b)	Unparallel lines clustering	Railway	60.9 %	26.8967	20
SegRail (b+)	Parallel lines clustering	Railway	60.9 %	17.1452	20
SegRail (c)	Map correlation	Railway	60.9 %	9.2753	20

Further details in the paper :

A. Mahtani, N. Chouchani, M. Herbreteau, D. Rafin, **Enhancing Autonomous Train Safety Through A Priori-Map Based Perception**, 4th International Conference on Reliability, Safety and Security of Railway Systems, 2022.

Results and analysis

Analysis 2 : Qualitative result of the correction process (c)



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Work in progress

- Preliminary Risk Analysis (PRA)

  - Safety Management Plan (SMP)
  - Preliminary Risk Analysis (PRA)
  - Allocation of requirements
  - Definition of SIL levels by function

Examples of SIL2 functions :

Monitor Environment
Monitor on-board situations
Monitor on-board passengers
Monitor train access door

Next step

- Failure Mode, Effects & Criticality Analysis (FMECA)

Autonomous system level

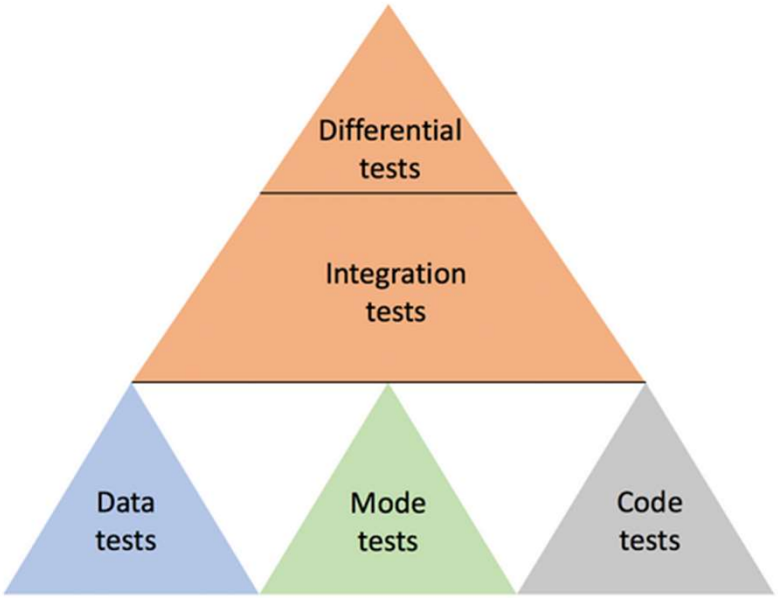
Security objectives: specification, allocation and traceability
Demonstration strategy: security processes and activities
Safety evidence: testing, simulation and verification

Next step

- Failure Mode, Effects & Criticality Analysis (FMECA)

AI technique level

Formal verification
Scenario (ODD)-based testing
Simulation testing
Real (Closed course) mode testing



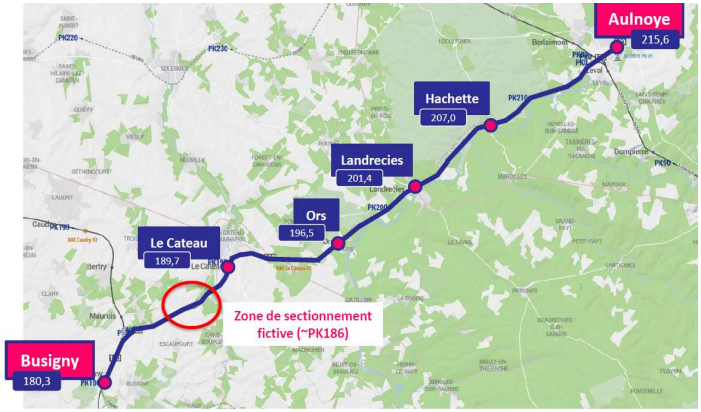
Test pyramid for a machine learning system

Conformity with existing standards

- UL4600 (2019): Standard for safety for the evaluation of autonomous products
- ISO/IEC TR 29119-11 (2020): Software and systems engineering - Software testing - Part 11: Guidelines on the testing of AI-based systems
- DIN SPEC 92001 (2021): Artificial Intelligence – life cycle processes and quality requiements Part 2 Robustesse
- ISO/IEC TR 20028 (2020): Artificial Intelligence – Overview of trustworthiness in artificial intelligence

Next step

- Real-time application on a train's prototype

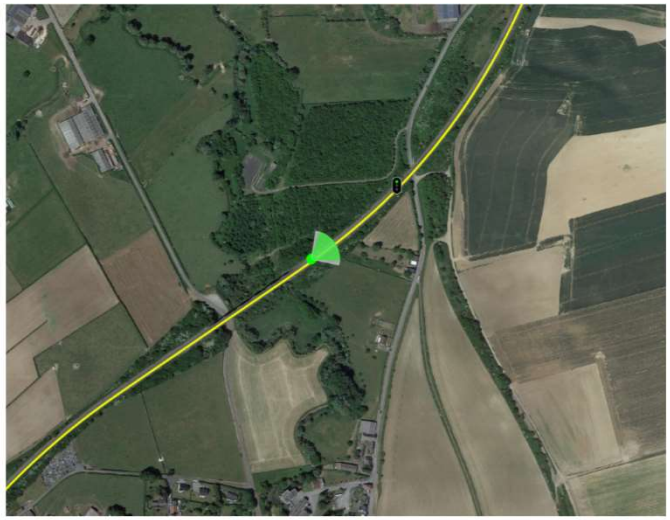


Railway tests in France

Thermal camera

Long range camera
Mid rage camera

2x Lidar



Train's positioning system

THALES

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Thank you !

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