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Digital Twin Development for Test Site: Foundation for Innovative Cost-Effective Train Positioning Alignment

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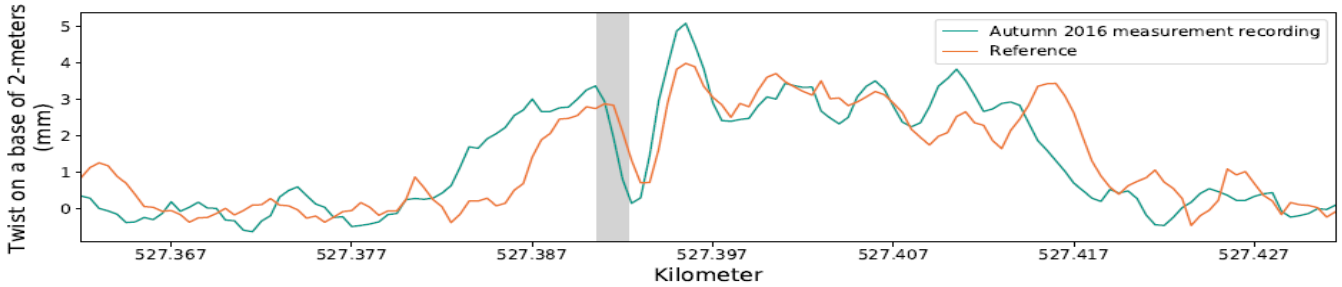
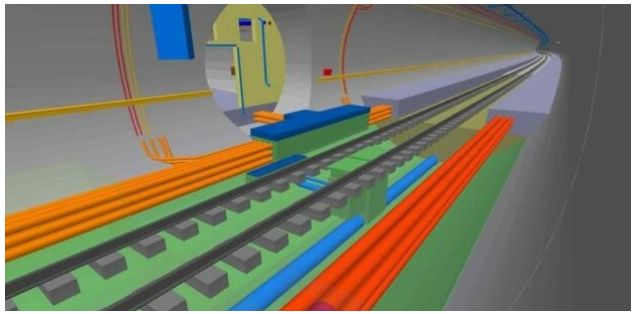
Introduction

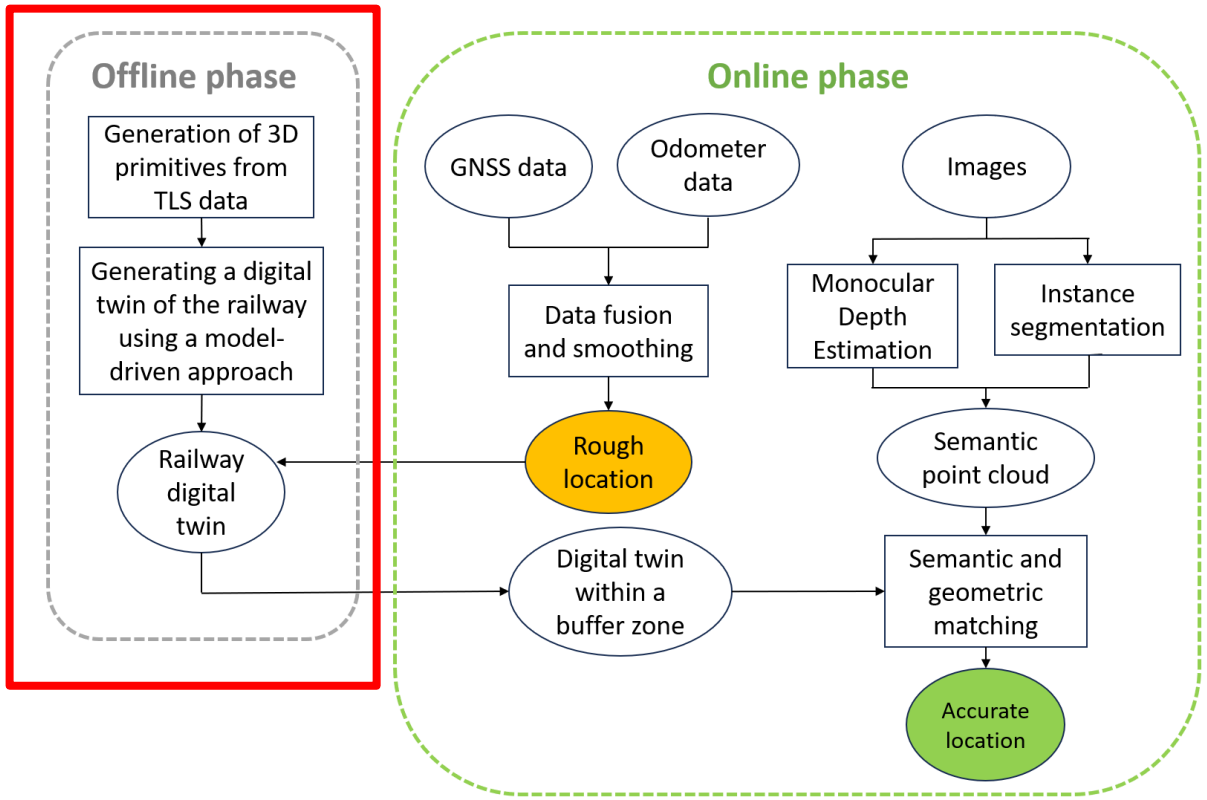
- Train positioning based on GNSS can be unreliable.



- Particularly pronounced for regional railway due to valleys, tunnels and other geographical challenges.
- Bad train positioning is not ideal for ERTMS, ECTS level 3.
- FP6 Task 3.4 and 8.5: Cost-effective fail-safe highly accurate train positioning on G1 lines
- Use of digital twin and image recognition to improve train position.

Proposed Method

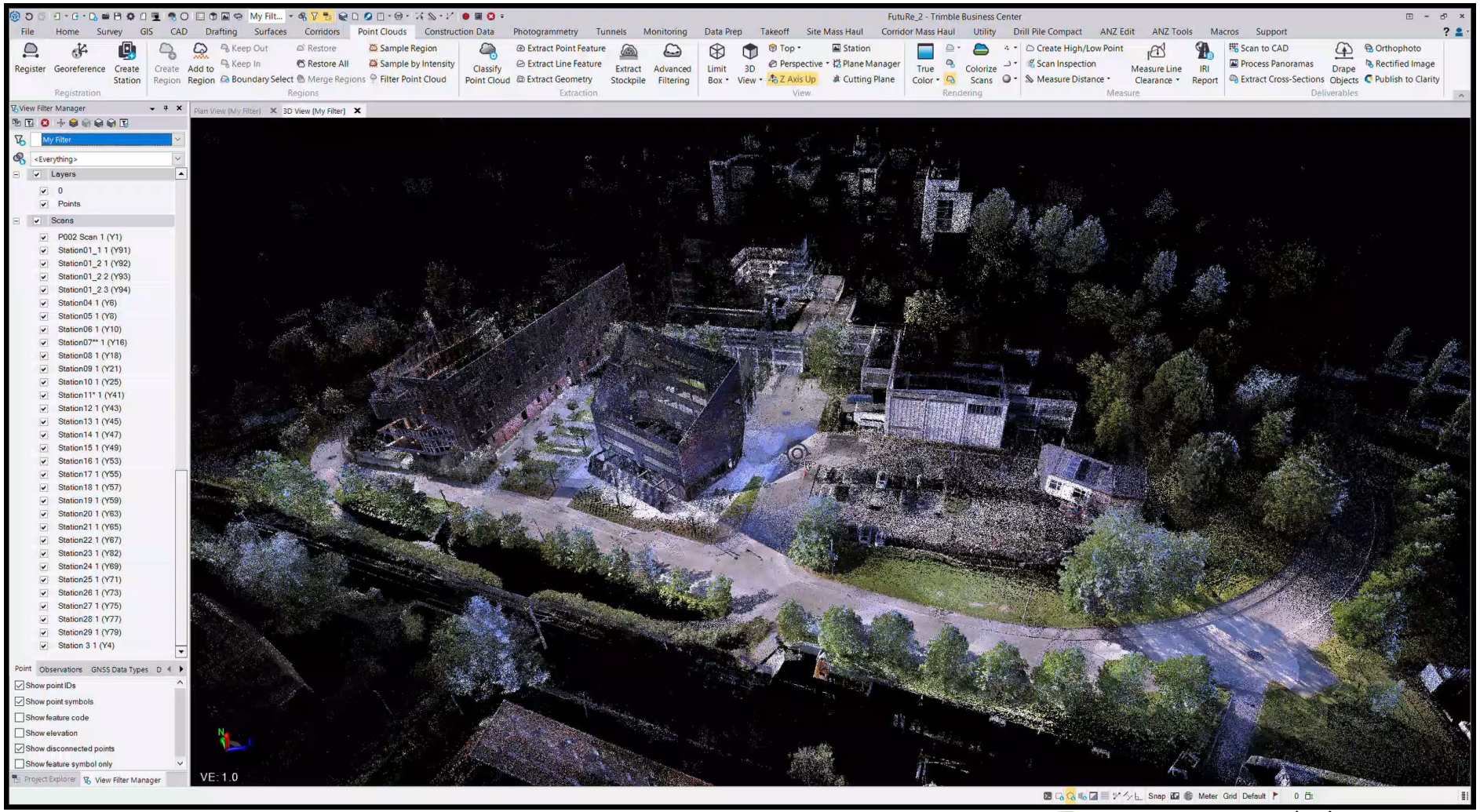




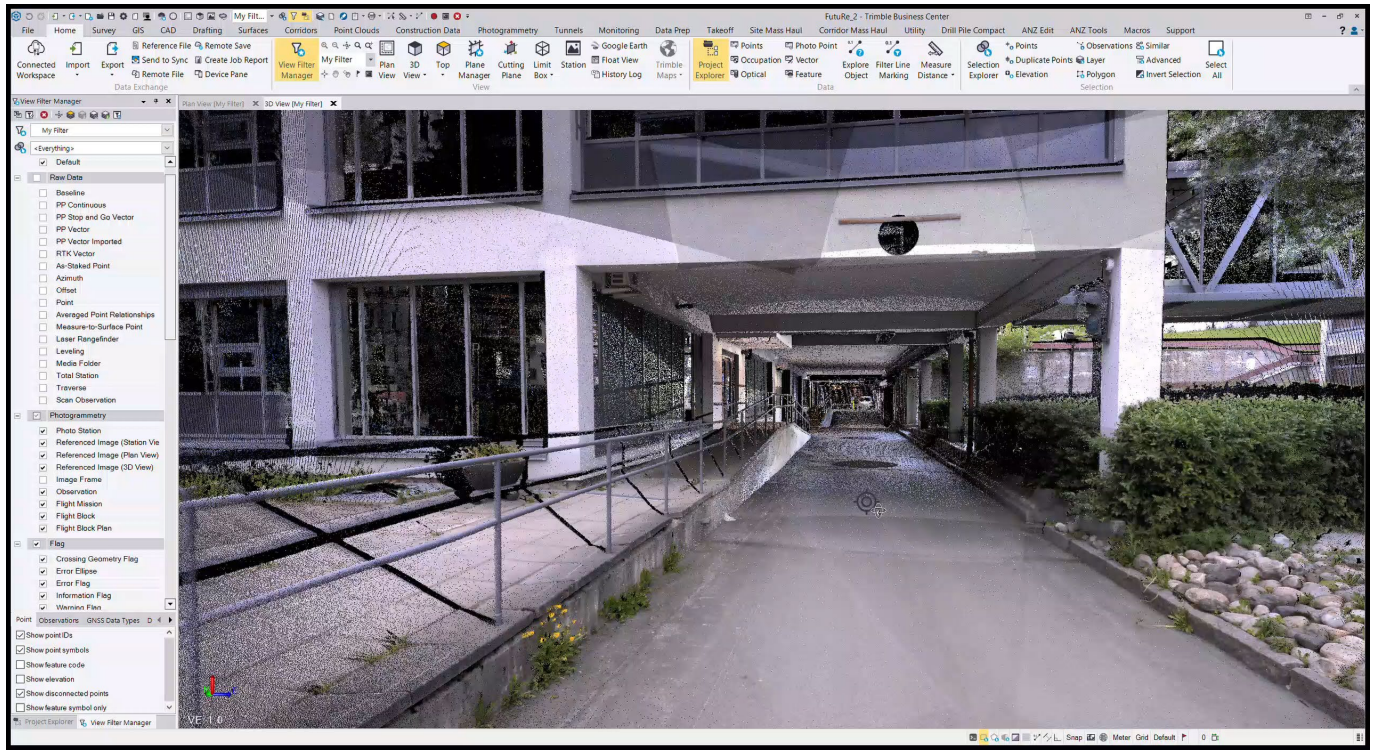
Test Site at NTNU

Data Collection

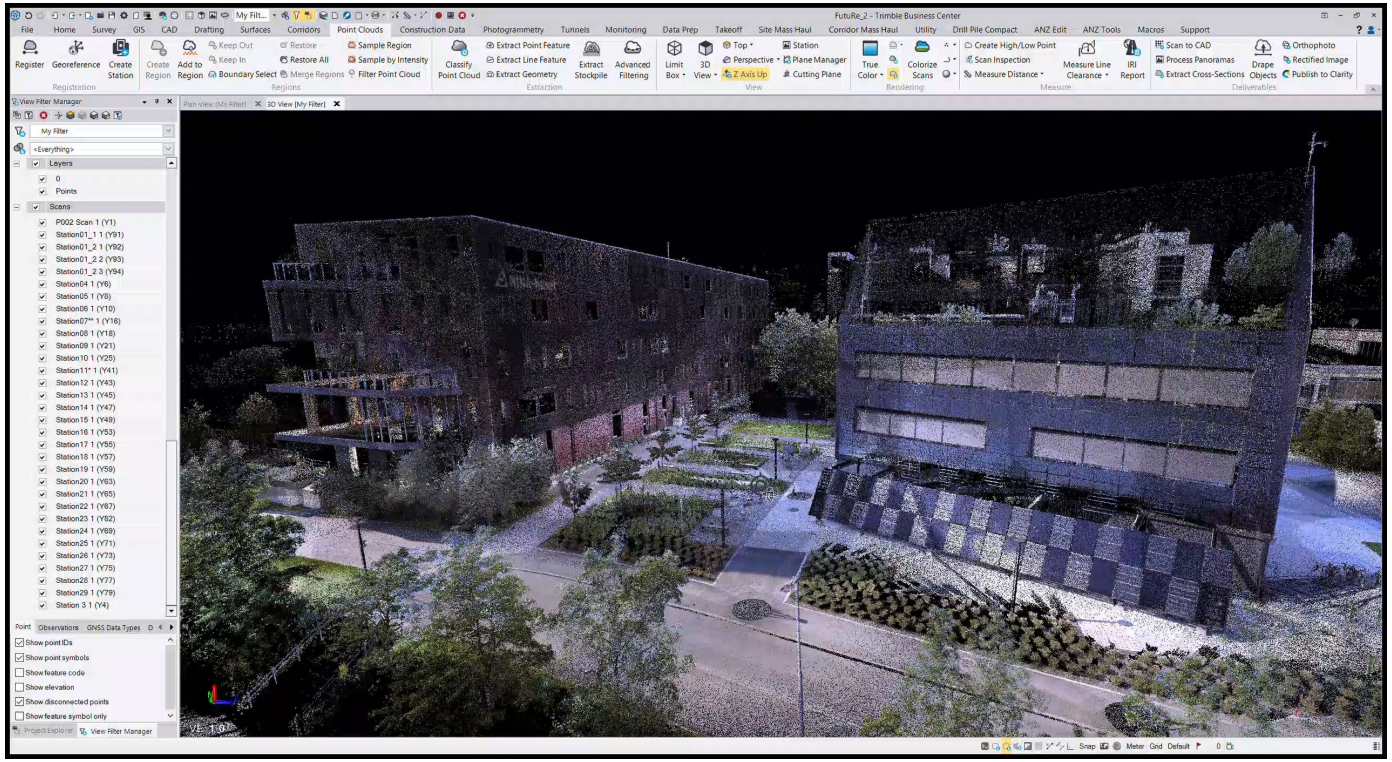
Test Site Digital Twin



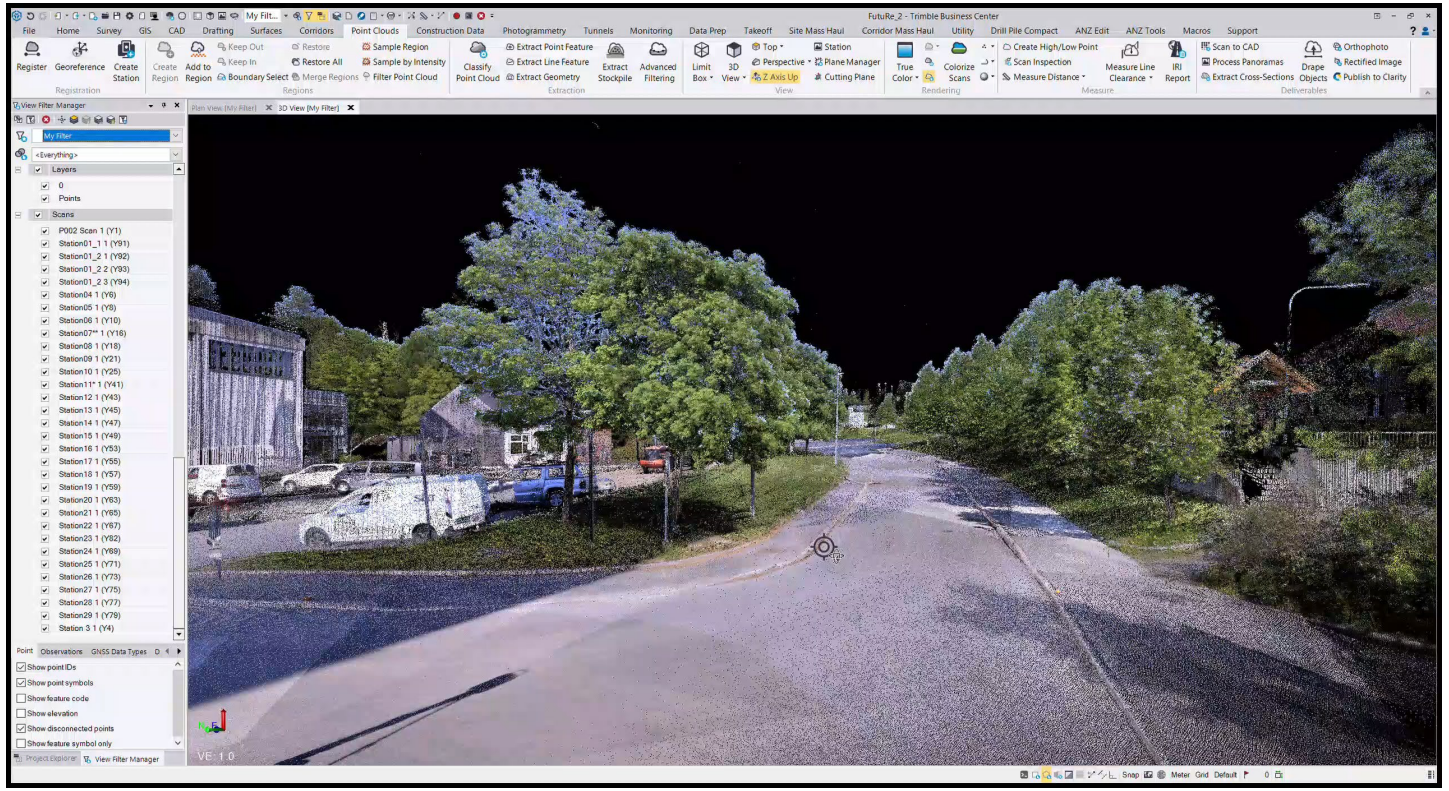
Simulated Tunnel



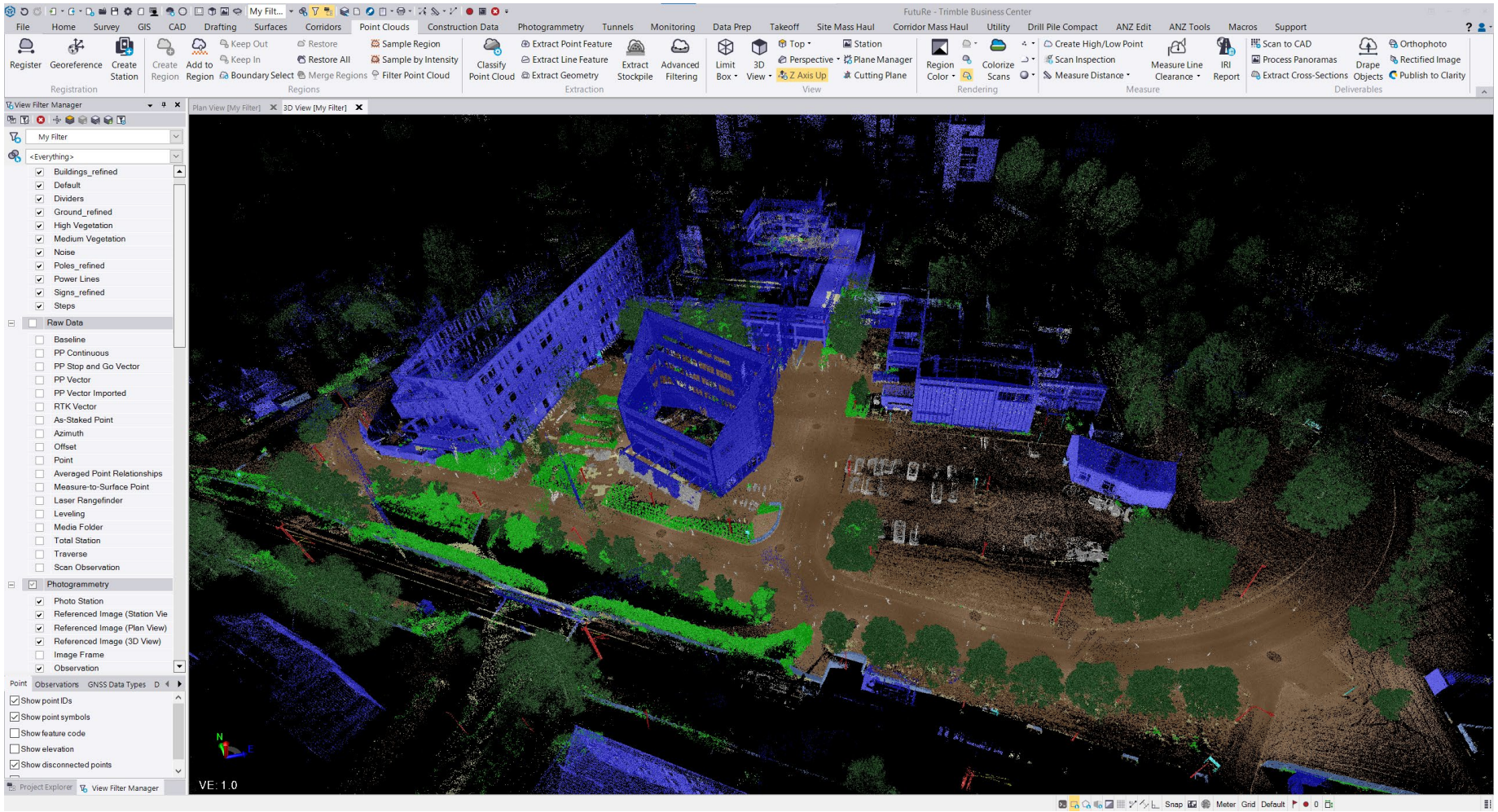
Simulated Valley



Simulated Trackside Objects

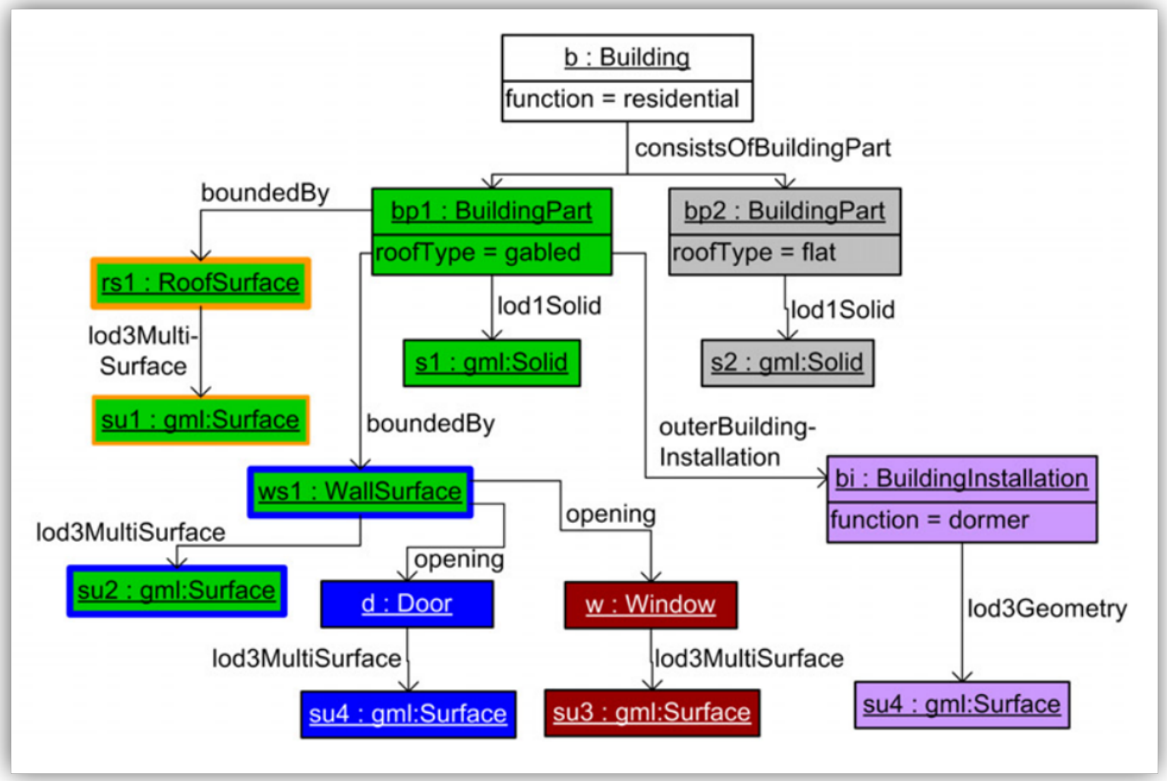


Semantic Labelling



To complete the Digital Twin

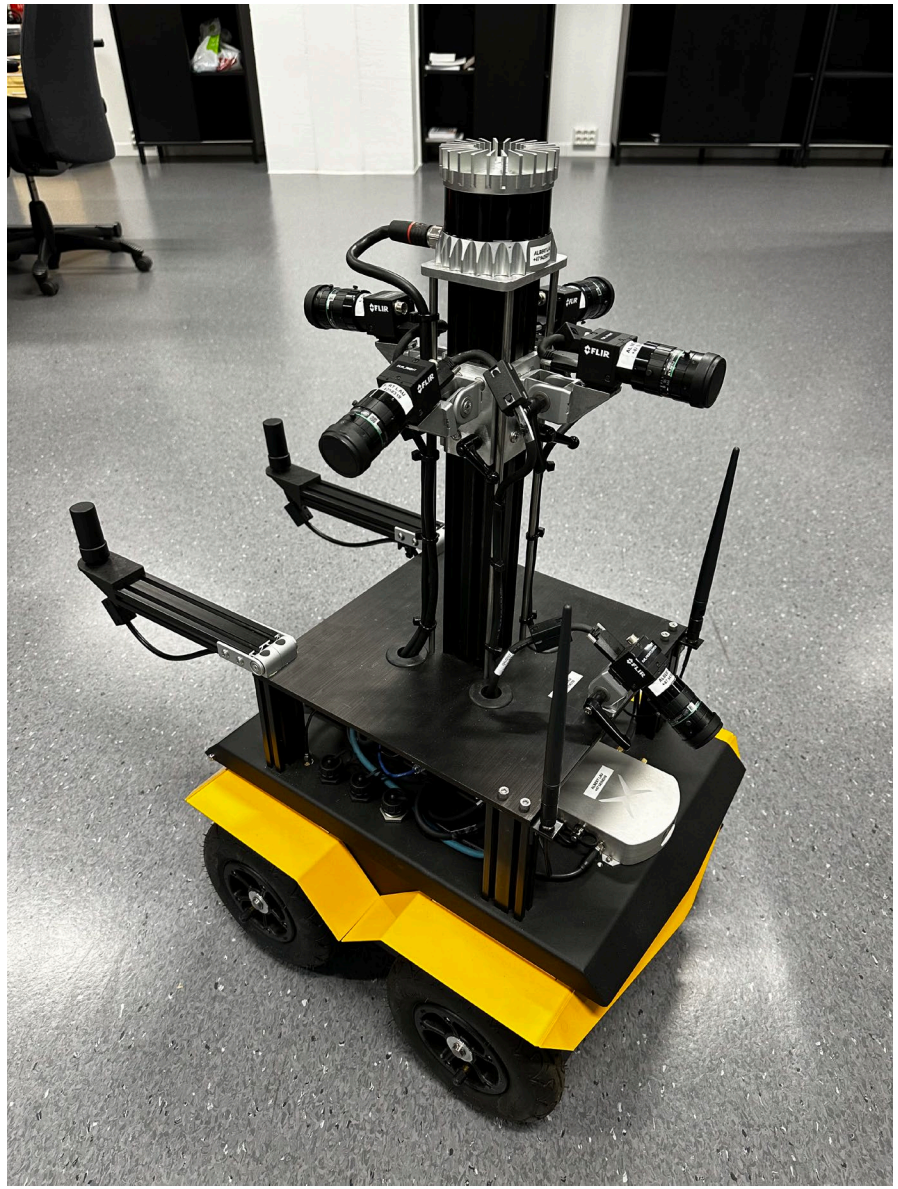
- Define CityGML Schema of the test site objects.
- Storing the 3D environment in the CityGML format.



Gröger, Gerhard, and Lutz Plümer. "CityGML–Interoperable semantic 3D city models." ISPRS Journal of Photogrammetry and Remote Sensing 71 (2012): 12-33.

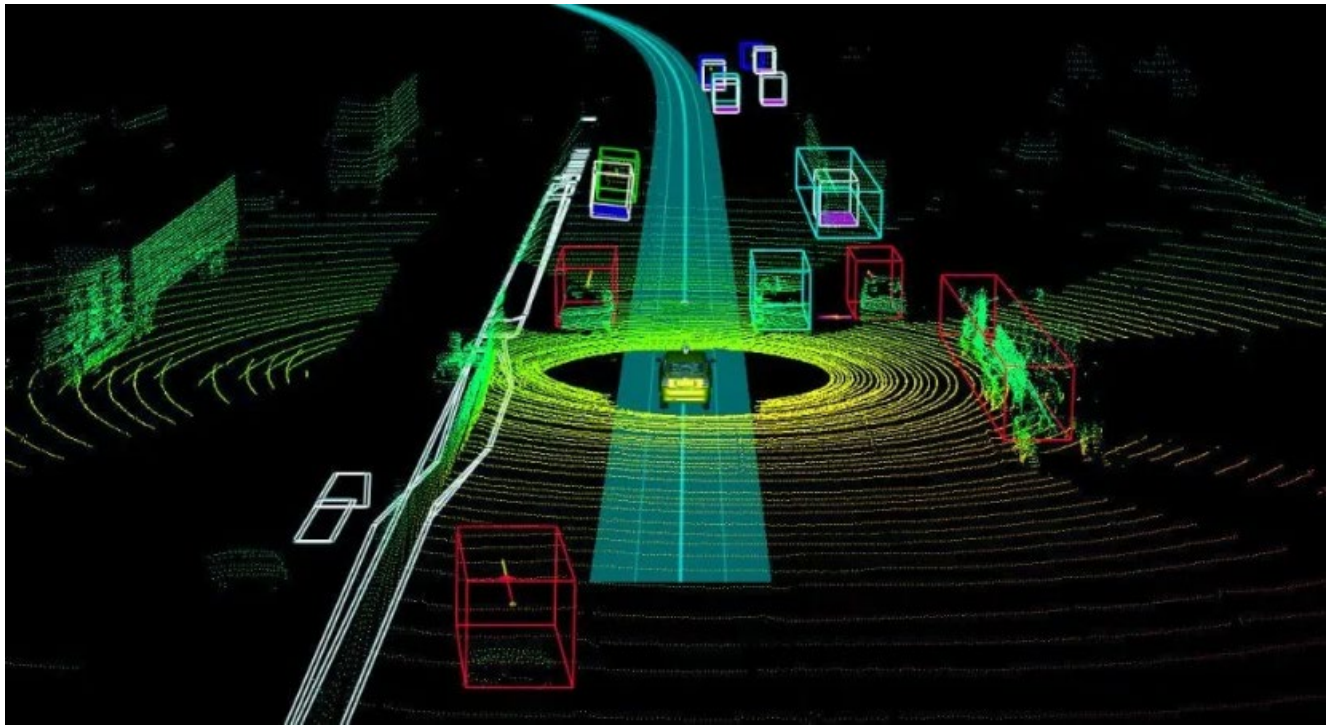
To simulate the train

- Unmaned ground vehicle (Jackal)
- Positioning sensors
  - 5 cameras
  - GNSS
  - Odometer
- In addition:
  - GNSS RTK
  - Lidar
  - On-board computer (data live-streaming)

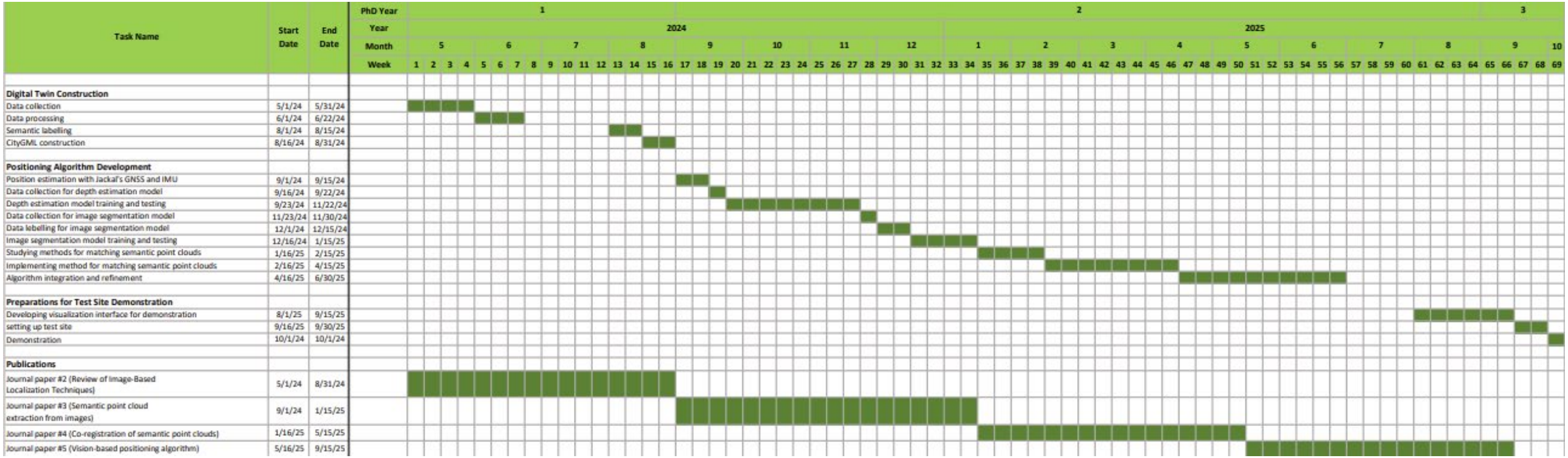


Next Steps

- Extracting semantic point clouds from images captured by onboard cameras in real-time.
- Matching the extracted features with the digital twin to obtain highly accurate positions.



Test site demonstration – Oct. 2025



Task Name	Start Date	End Date
Digital Twin Construction		
Data collection	5/1/24	5/31/24
Data processing	6/1/24	6/22/24
Semantic labelling	8/1/24	8/15/24
CityGML construction	8/16/24	8/31/24
Positioning Algorithm Development		
Position estimation with Jackal's GNSS and IMU	9/1/24	9/15/24
Data collection for depth estimation model	9/16/24	9/22/24
Depth estimation model training and testing	9/23/24	11/22/24
Data collection for image segmentation model	11/23/24	11/30/24
Data labelling for image segmentation model	12/1/24	12/15/24
Image segmentation model training and testing	12/16/24	1/15/25
Studying methods for matching semantic point clouds	1/16/25	2/15/25
Implementing method for matching semantic point clouds	2/16/25	4/15/25
Algorithm integration and refinement	4/16/25	6/30/25
Preparations for Test Site Demonstration		
Developing visualization interface for demonstration	8/1/25	9/15/25
setting up test site	9/16/25	9/30/25
Demonstration	10/1/24	10/1/24
Publications		
Journal paper #2 (Review of Image-Based Localization Techniques)	5/1/24	8/31/24
Journal paper #3 (Semantic point cloud extraction from images)	9/1/24	1/15/25
Journal paper #4 (Co-registration of semantic point clouds)	1/16/25	5/15/25
Journal paper #5 (Vision-based positioning algorithm)	5/16/25	9/15/25

Test site demonstration

- Use cases:
  1. Reduce railway track maintenance cost by providing accurate faulty track locations
  2. Provide accurate geo-positions of the train under challenging conditions
  3. Ensure continuous and precise geo-positioning of the train during periods of GNSS signal unavailability

Thank you

FP6-FutuRe
Cost effective regional lines

Jernbane-
direktoratet