



Urban scene perception and environment model synthesis from multisensorial spatial data

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Research background

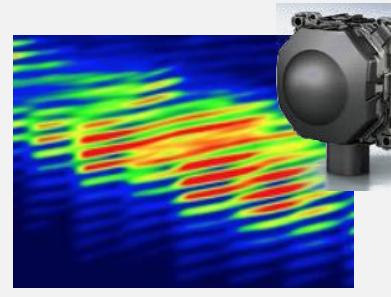
- HUN-REN Institute for Computer Science and Control (SZTAKI) - Machine Perception Research Laboratory
 - Machine based interpretation and analysis of our environment from various sensor measurements



High resolution cameras



Thermal cameras



Radar



LIDAR laser scanners

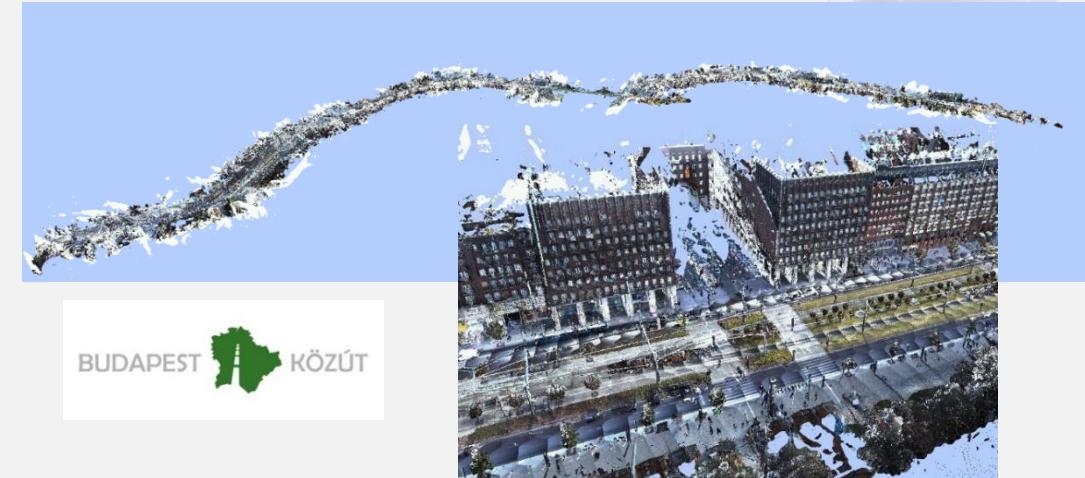
- Goals in the field of urban transport monitoring and utilization:
 - Automated environment perception tasks for self-driving cars, wheeled or foot-powered mobile robots and UAVs
 - Generating detailed virtual 3D environment models for self-localization and map generation of autonomous vehicles
- Main challenge: incomplete spatial data
 - Limited spatial/temporal resolution
 - Occluded or hidden scene segments
 - Measurement noise, changes in external illumination, weather

Level 5 urban 3D environment perception with GIS background

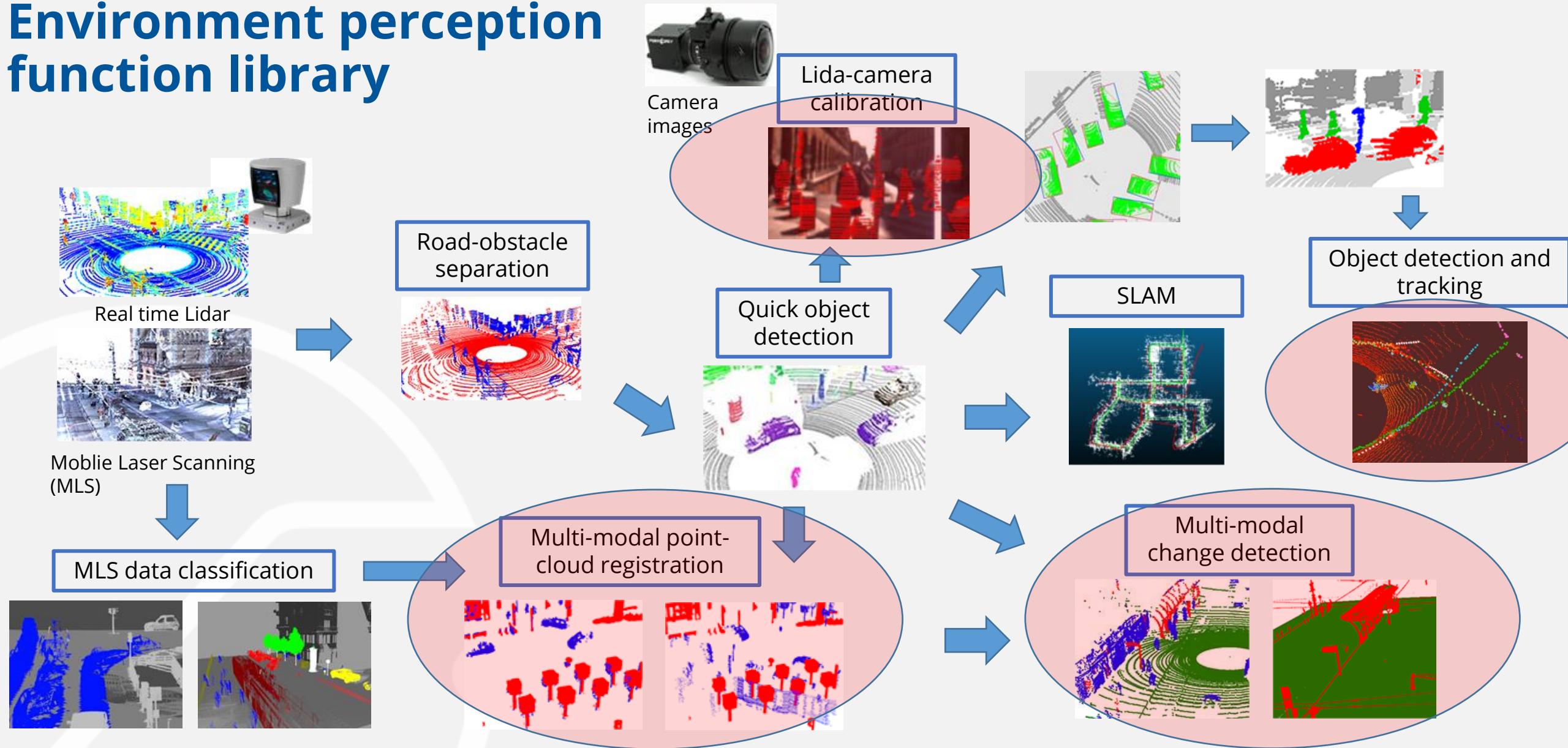
- SZTAKI/SZE car-mounted multi-sensory platform



High resolution 3D city model



Environment perception function library



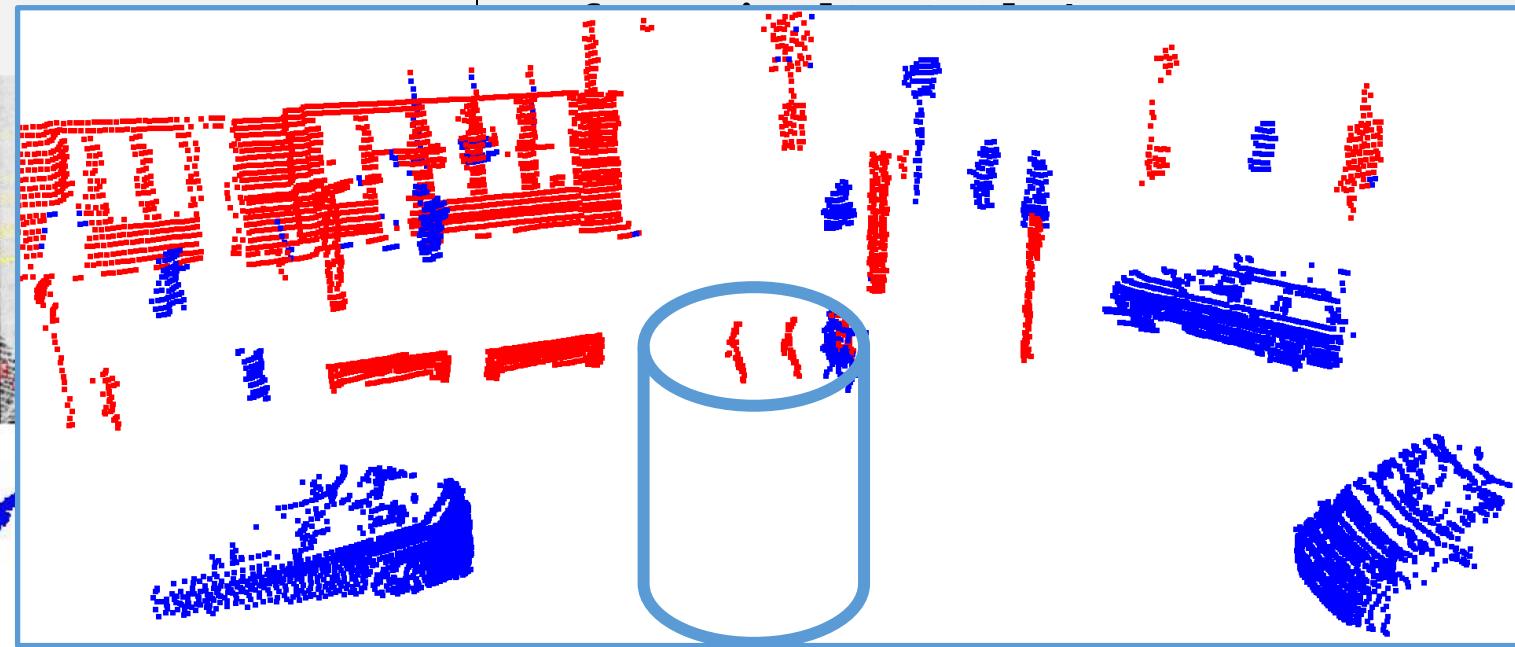
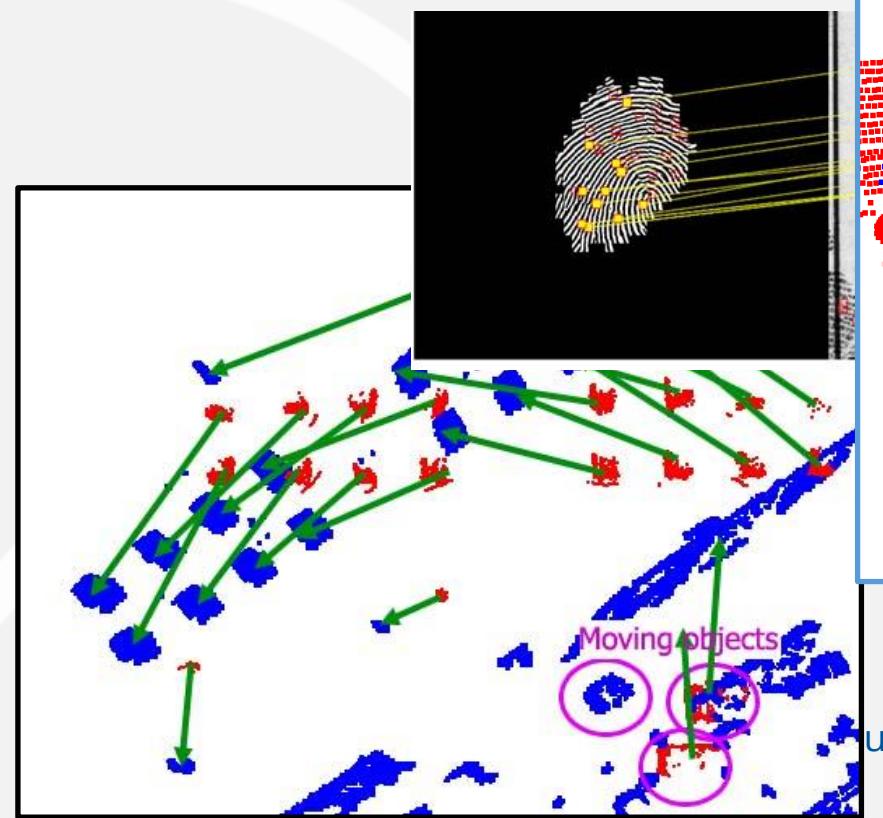
Publication: Cs. Benedek, A. Majdik, B. Nagy, Z. Rózsa and T. Szirányi: "Positioning and Perception in LIDAR point clouds," *Digital Signal Processing: A Review Journal*, Elsevier, 2021

Point cloud registration

Challenge: very different point cloud density

Analogy: fingerprint minutiae matching

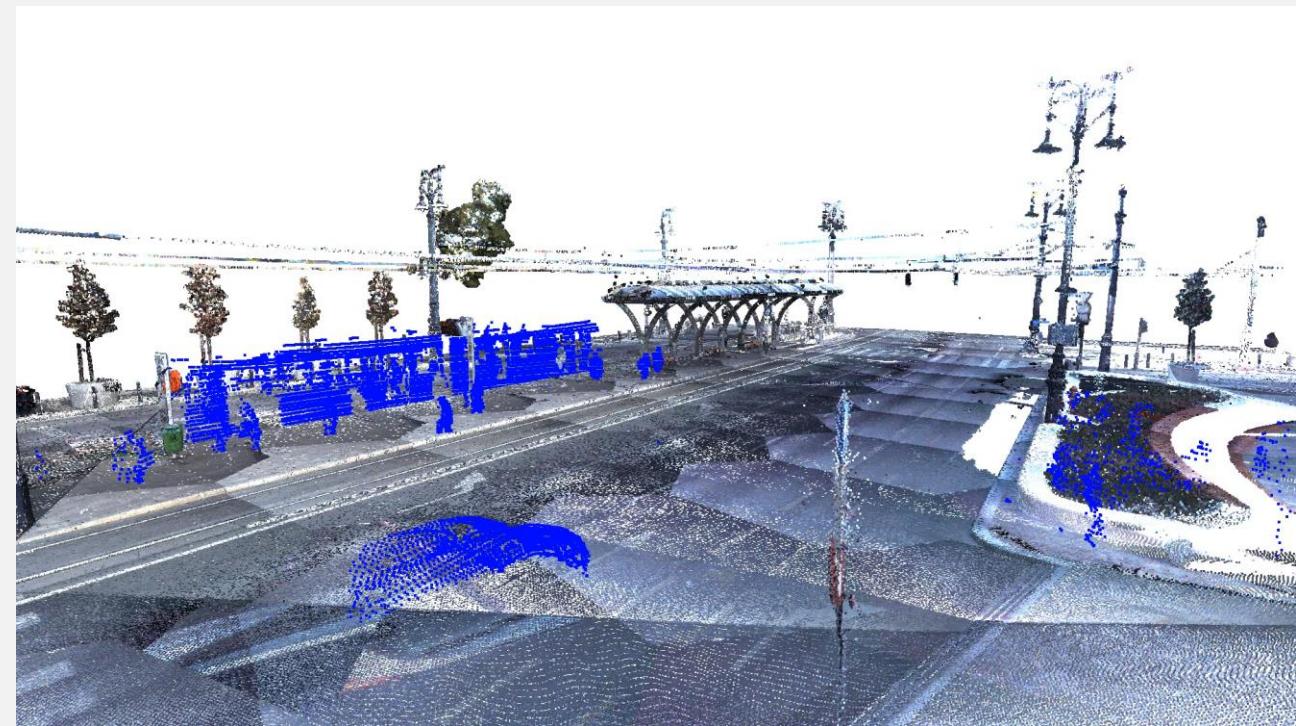
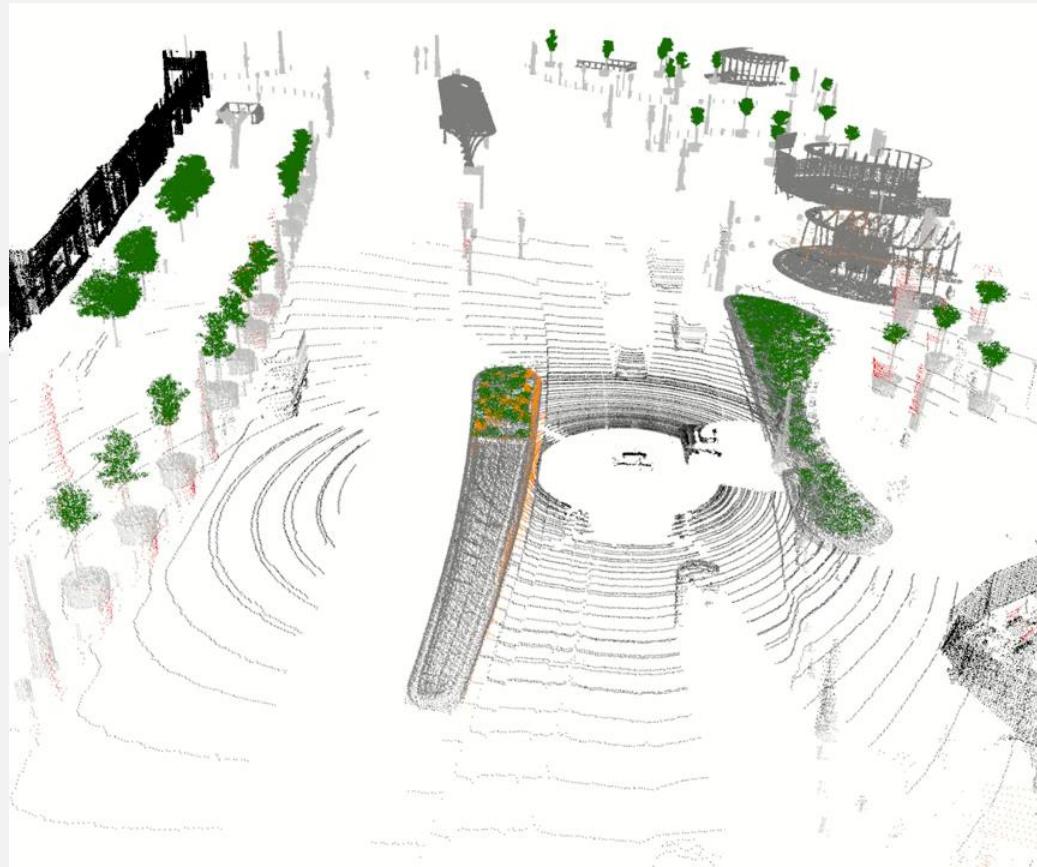
Generalized Hough transform



5

```
procedure Alignment(F1, F2, T)
    C1 <- ObjectDetect(F1)
    C2 <- ObjectDetect(F2)
    Initialize 4D accumulator array A
    for all o1 in C1 do
        for all o2 in C2 do
```

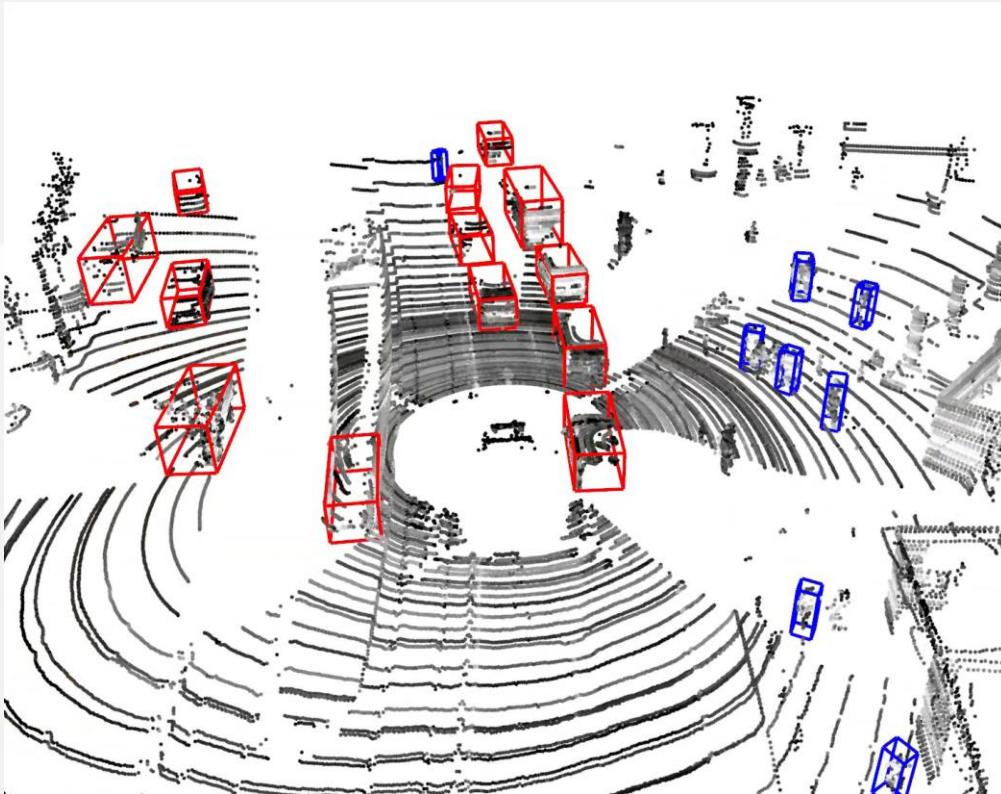
Self positioning in MLS map and motion detection



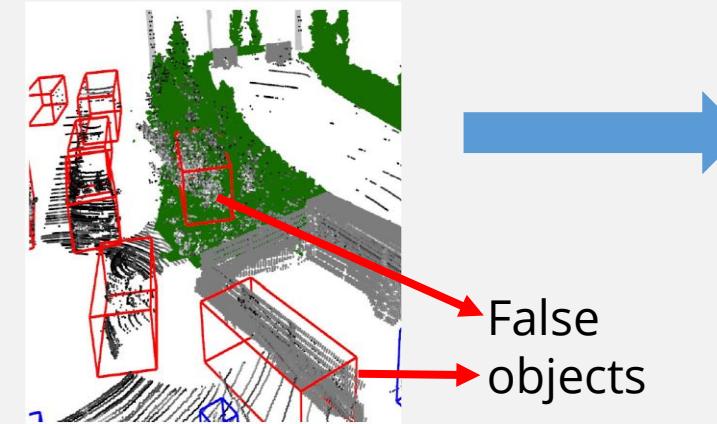
Publication: Ö. Zováthi, B. Nagy and Cs. Benedek: "Point Cloud Registration and Change Detection in Urban Environment Using an Onboard Lidar Sensor and MLS Reference Data," *International Journal of Applied Earth Observation and Geoinformation*, Elsevier, vol. 110, 202211

Enhancing SOA object detection using 3D environment map

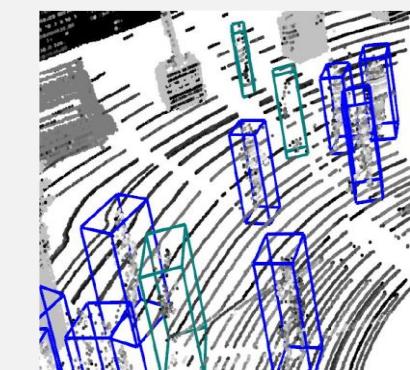
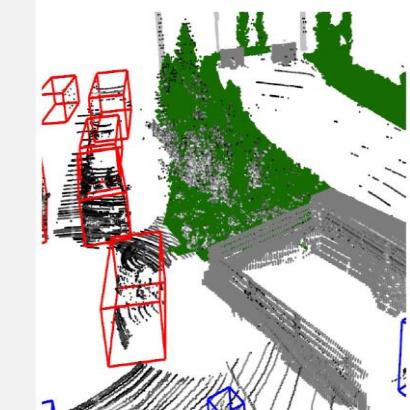
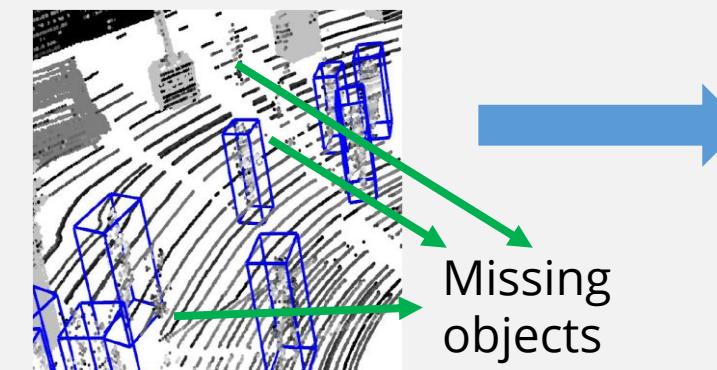
PointPillars: SOA Lidar object detection technique



Result of PointPillars detection

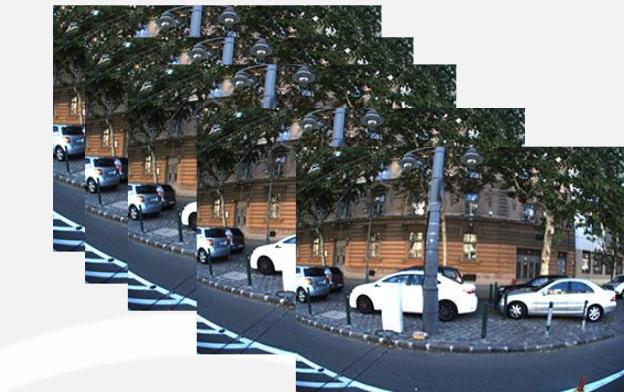


Proposed solution



Publication: Ö. Zováthi, B. Nagy and Cs. Benedek: "Exploitation of Dense MLS City Maps for 3D Object Detection", *International Conference on Image Analysis and Recognition (ICIAR)*, Póvoa de Varzim, Portugal, vol- 12131 of *Lecture Notes in Computer Science*, pp. 393-403, Springer, 2020

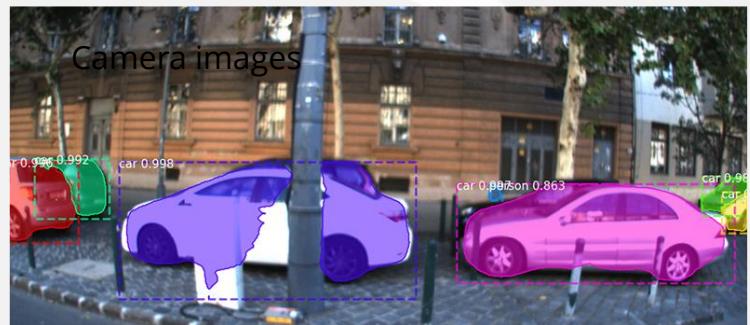
Lidar-camera targetless automatic calibration



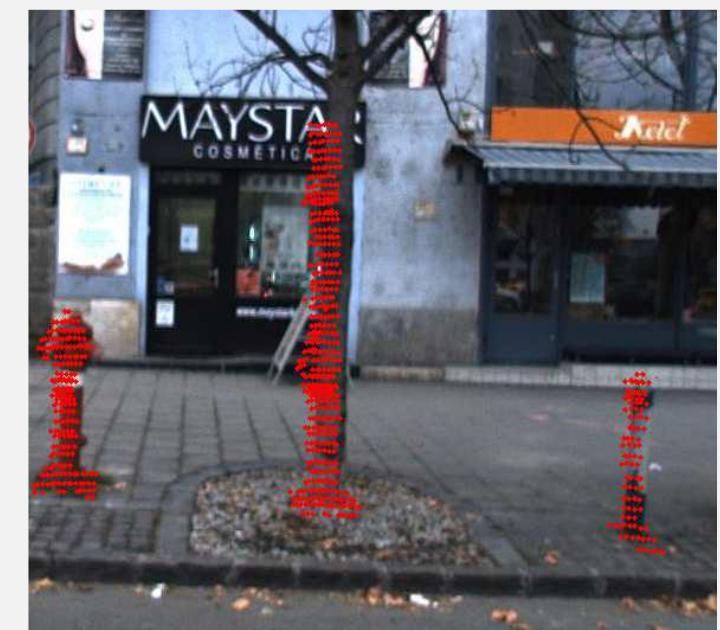
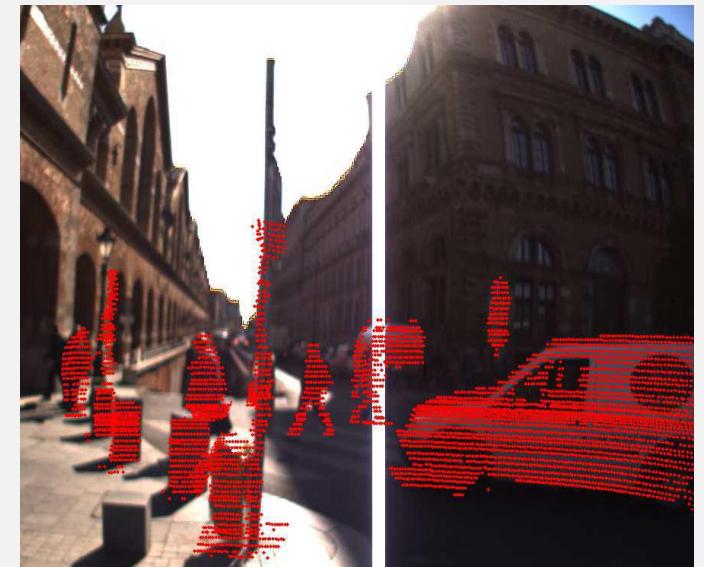
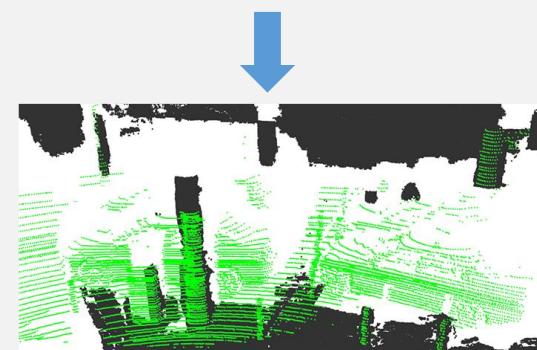
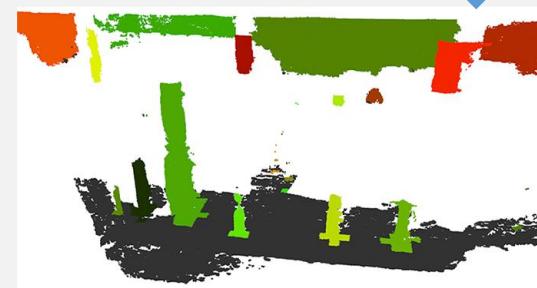
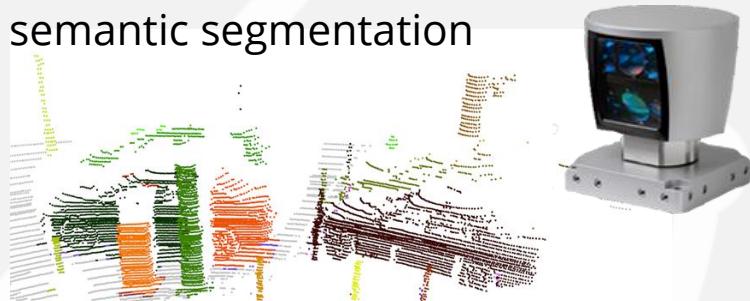
Structure
from Motion
(SfM)



SfM point cloud



2D semantic segmentation

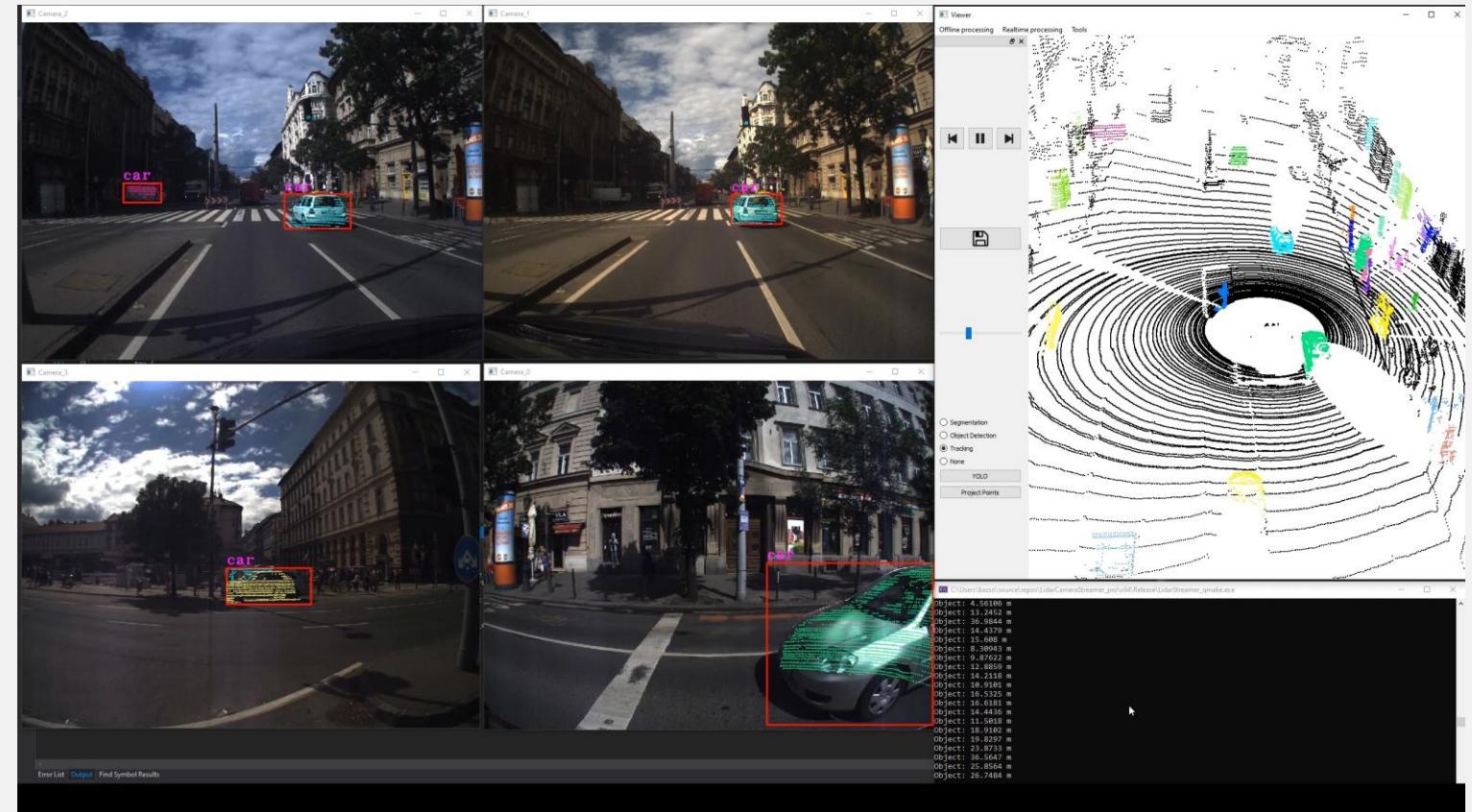


Publication: B. Nagy and Cs. Benedek: "On-the-Fly Camera and Lidar Calibration," *Remote Sensing*, vol 12, no. 7, article 1137, 2020

Experiments with our research platform



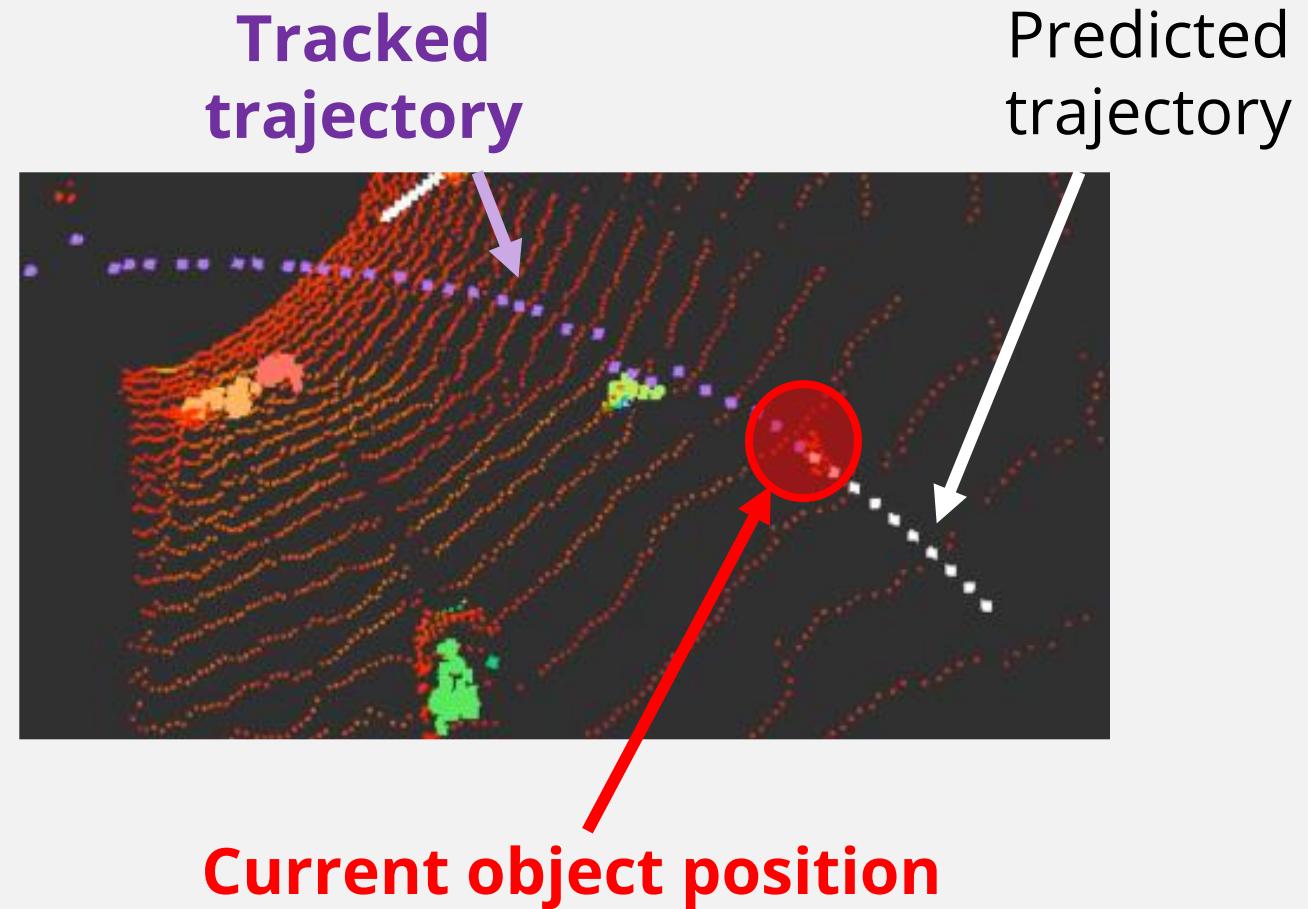
- Object recognition with machine learning in the camera images
- 3D object segmentation and tracking in Lidar point clouds
- Lidar-camera fusion



Experiments with our research platform



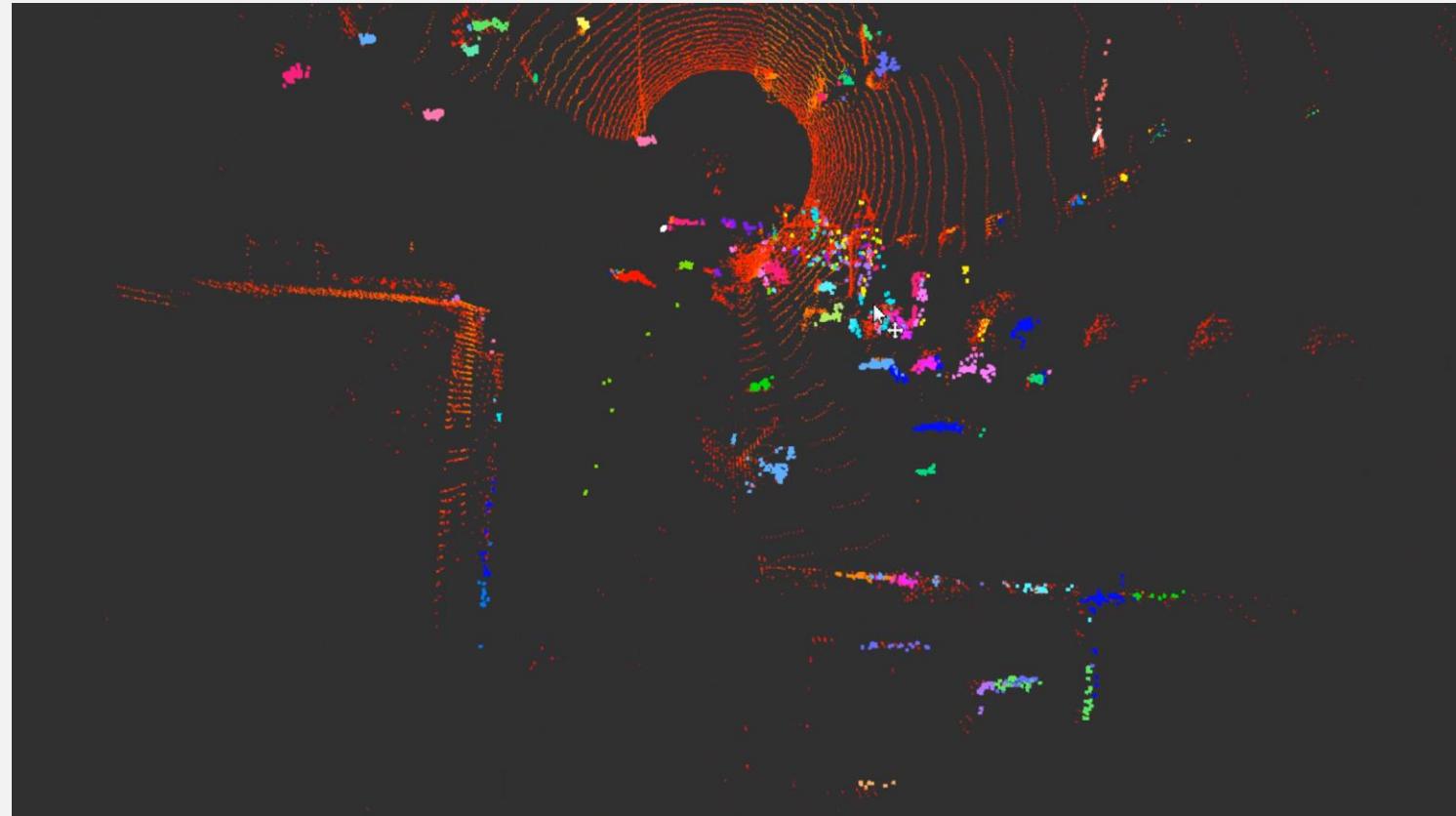
- Object tracking and trajectory prediction for the next 1-2 sec period (using Unscented Kalman Filter)



Experiments with our research platform



- Object tracking and trajectory prediction for the next 1-2 sec period (using Unscented Kalman Filter)



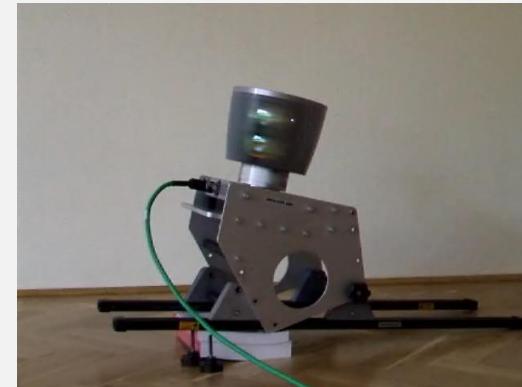
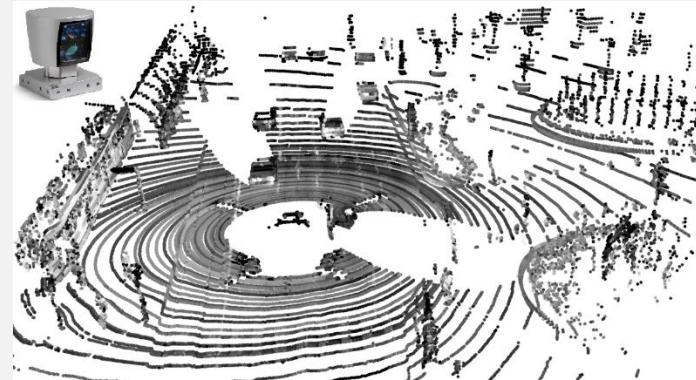
Until now : Velodyne HDL/Ouster



Rotating multi-beam Lidars



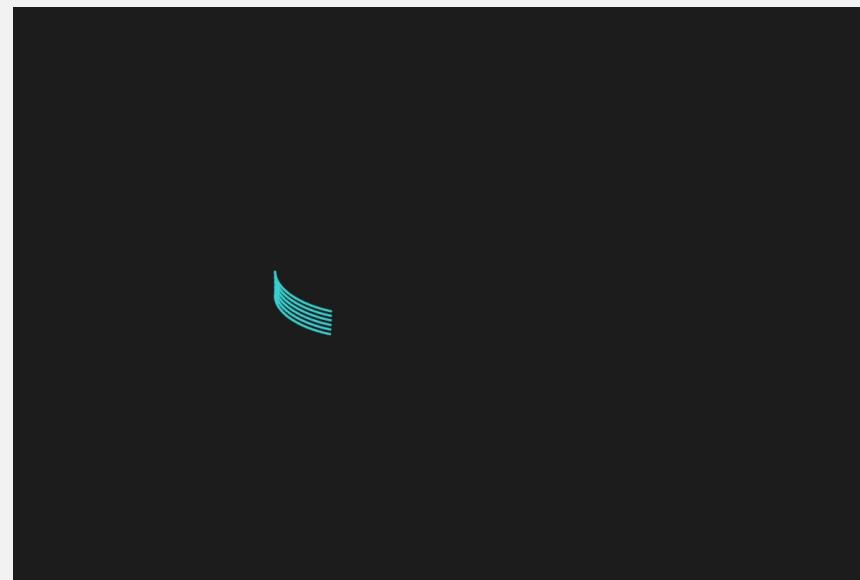
Drawbacks: low vertical resolution,
rotating components



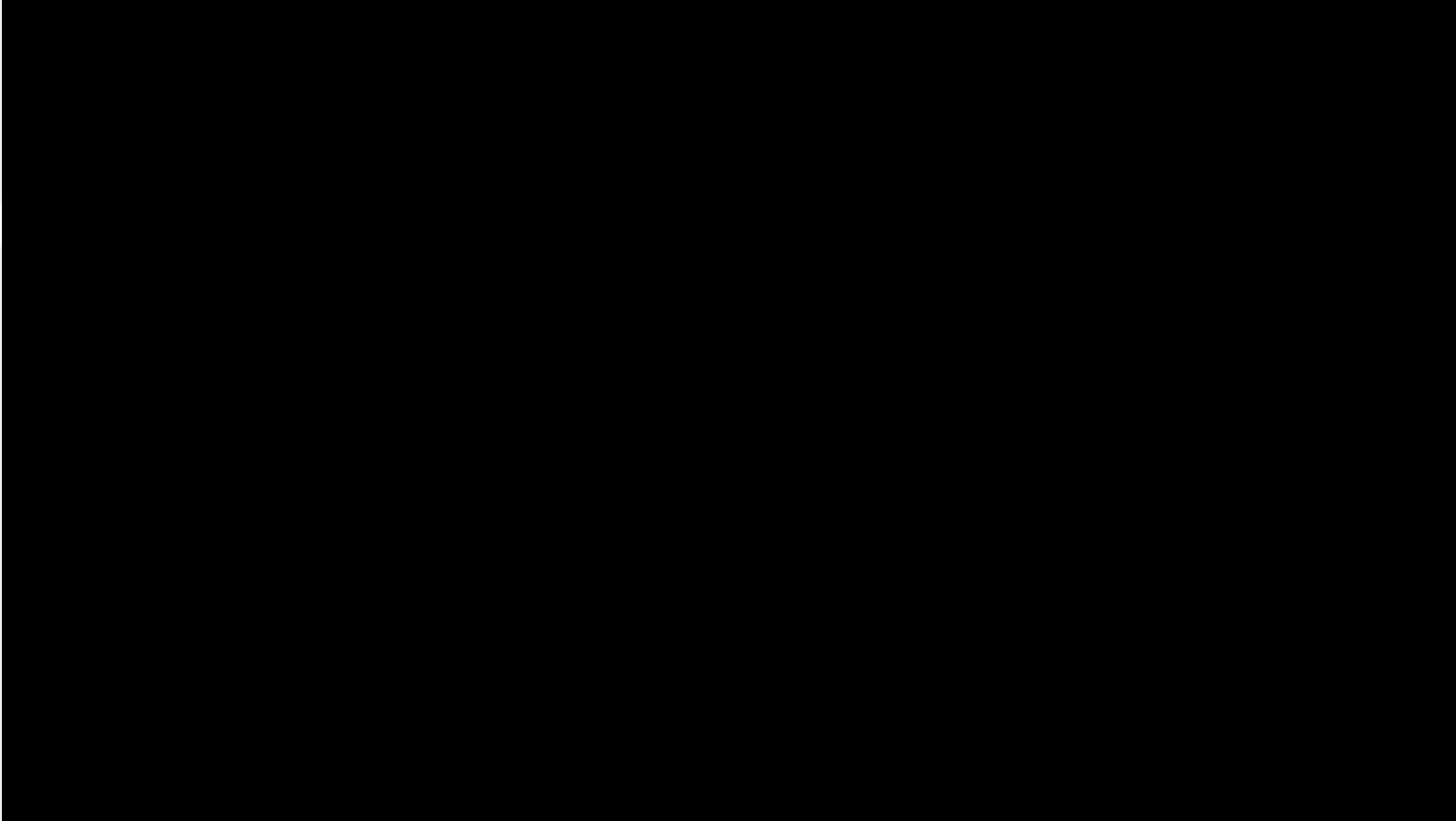
New: Livox Avia



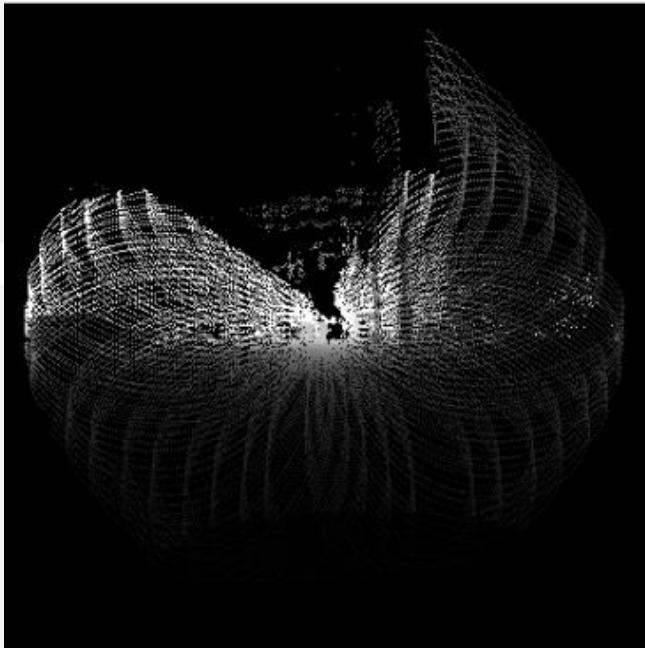
Non-repetitive circular scanning Lidar



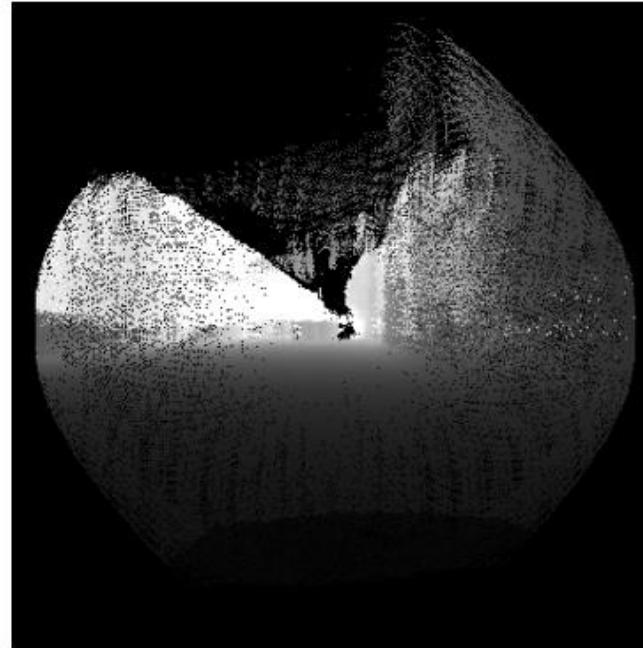
Application of low-resolution Lidars for complex scene analysis



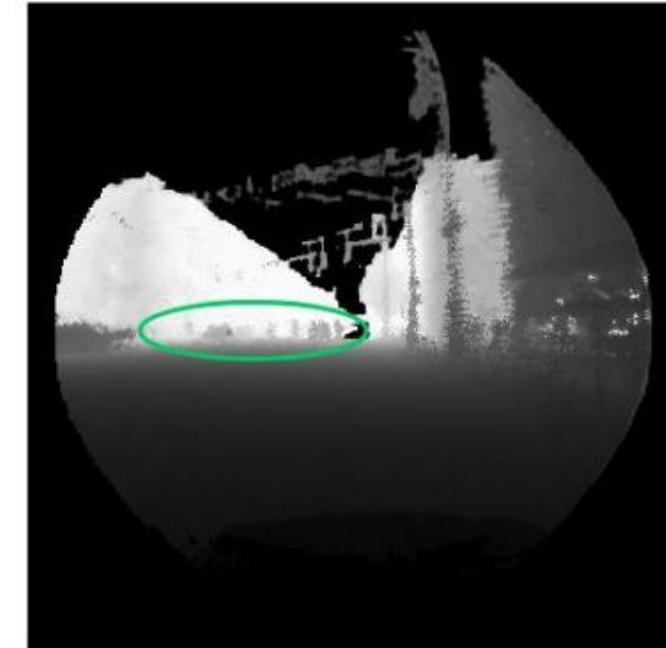
STDepthNet: densifying Livox point clouds with machine learning



Sparse Livox measurement
(200 ms integration time)
40% FoV coverage

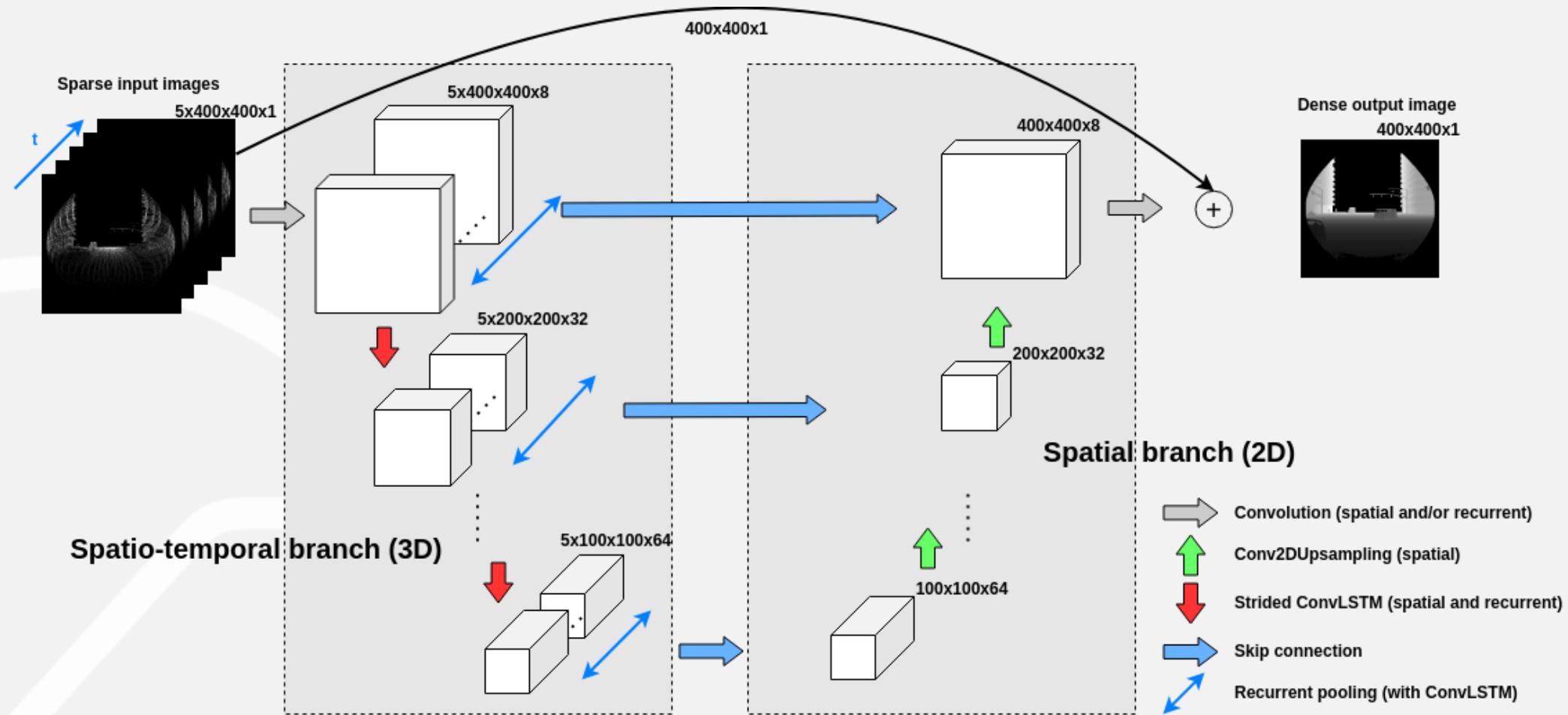


Dense Livox measurement
(1000 ms integration)
90% FoV coverage, BLUR

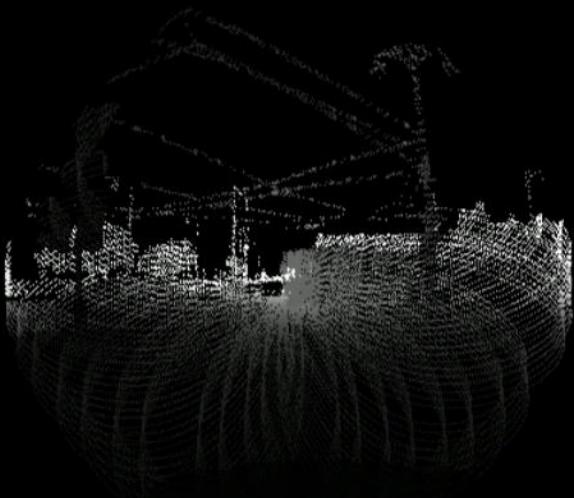


STDepthNet output

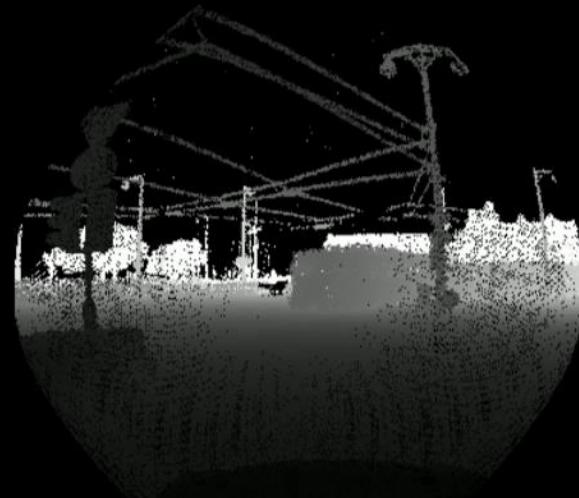
Livox based depth image completion from moving platform



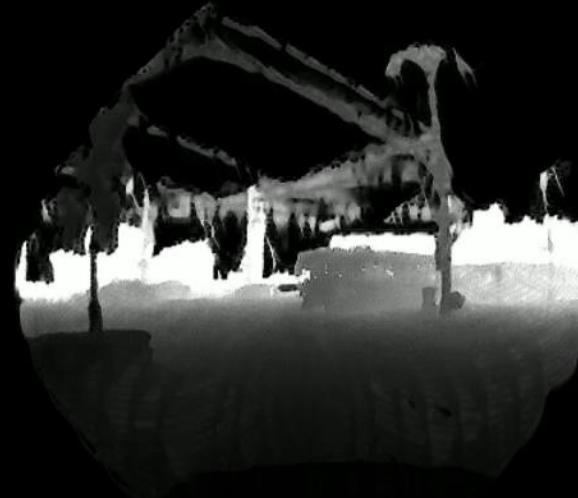
Ö. Zováthi, B. Pálffy, Zs. Jankó and Cs. Benedek: ST-DepthNet: A spatio-temporal deep network for depth completion using a single non-repetitive circular scanning Lidar, *IEEE Robotics and Automation Letters*, vol. 8, no. 6, pp. 3270-3277, 2023, IF: 5.2



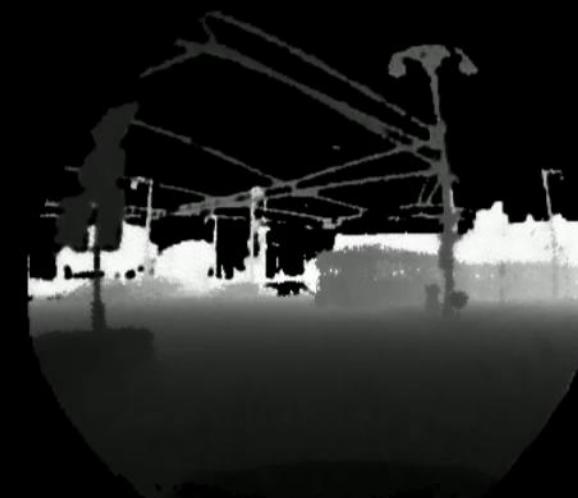
Narrow integration (200 ms)



Large integration (1 s)



Sparse-to-Dense



Proposed ST-DepthNet



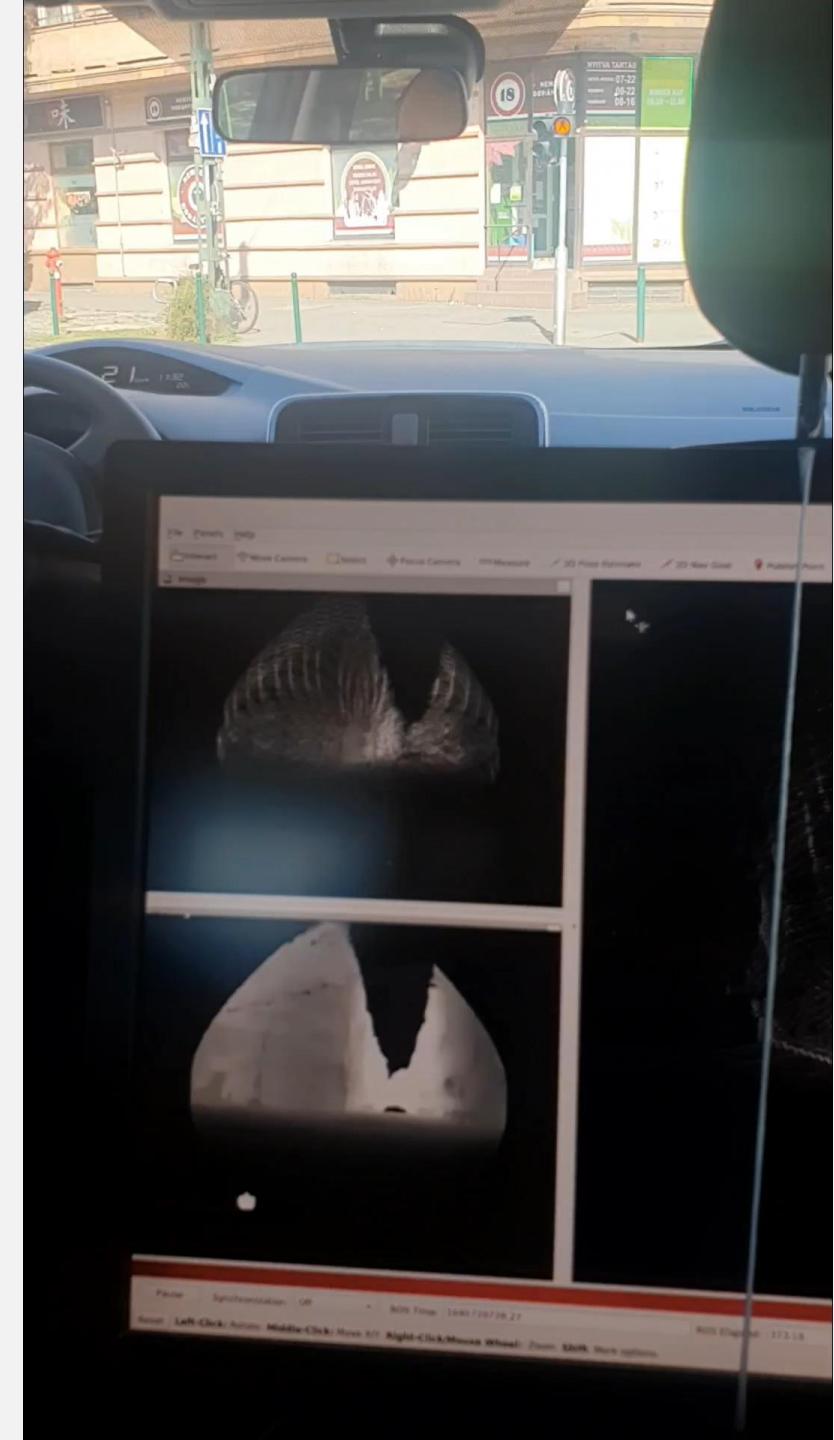
National Laboratory for Autonomous System - real time tests



Lexus (SZTAKI, BME)



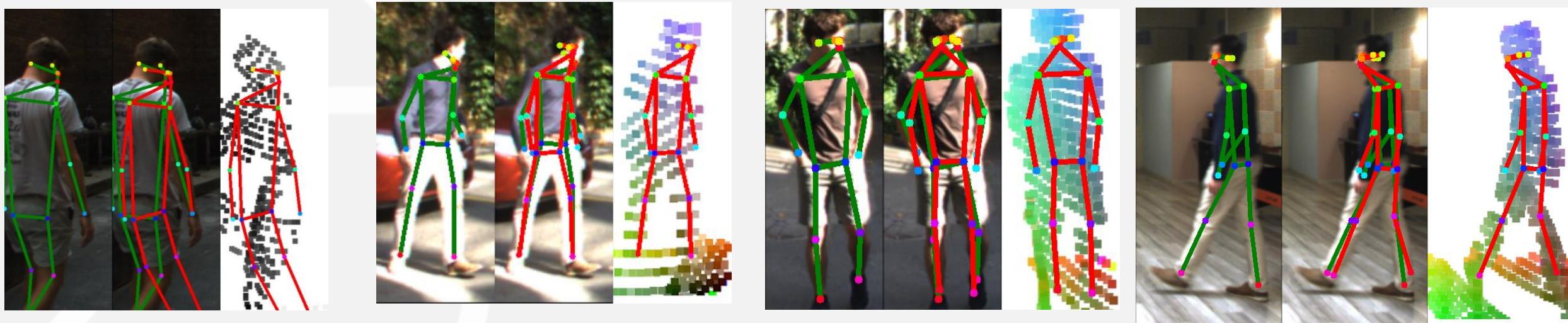
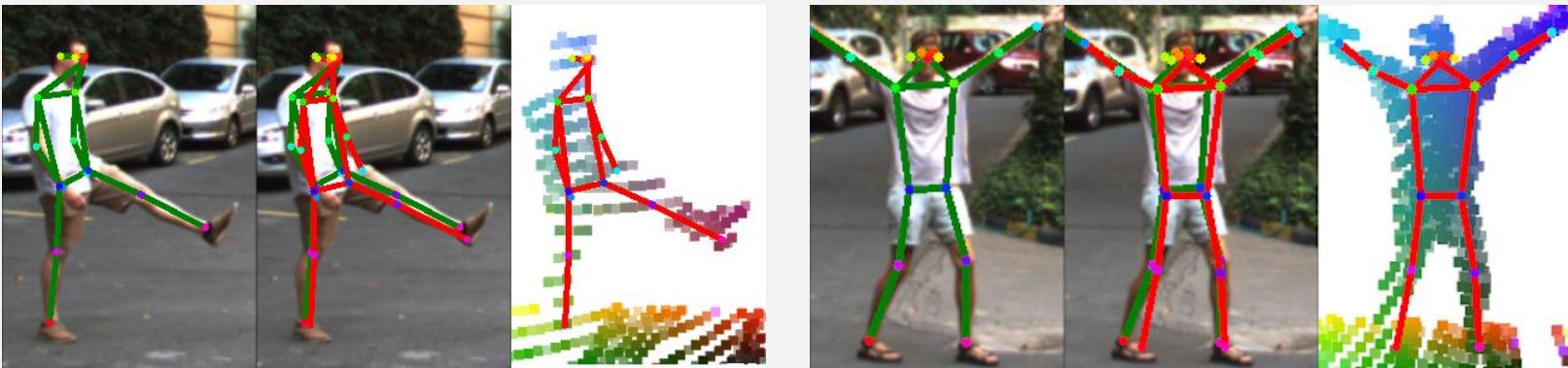
Nissan Leaf (SZE, SZTAKI)



Human pose detection

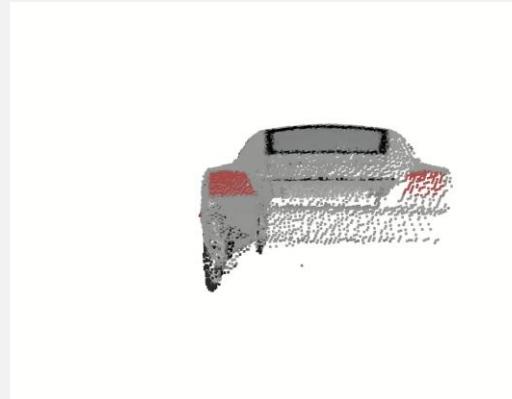
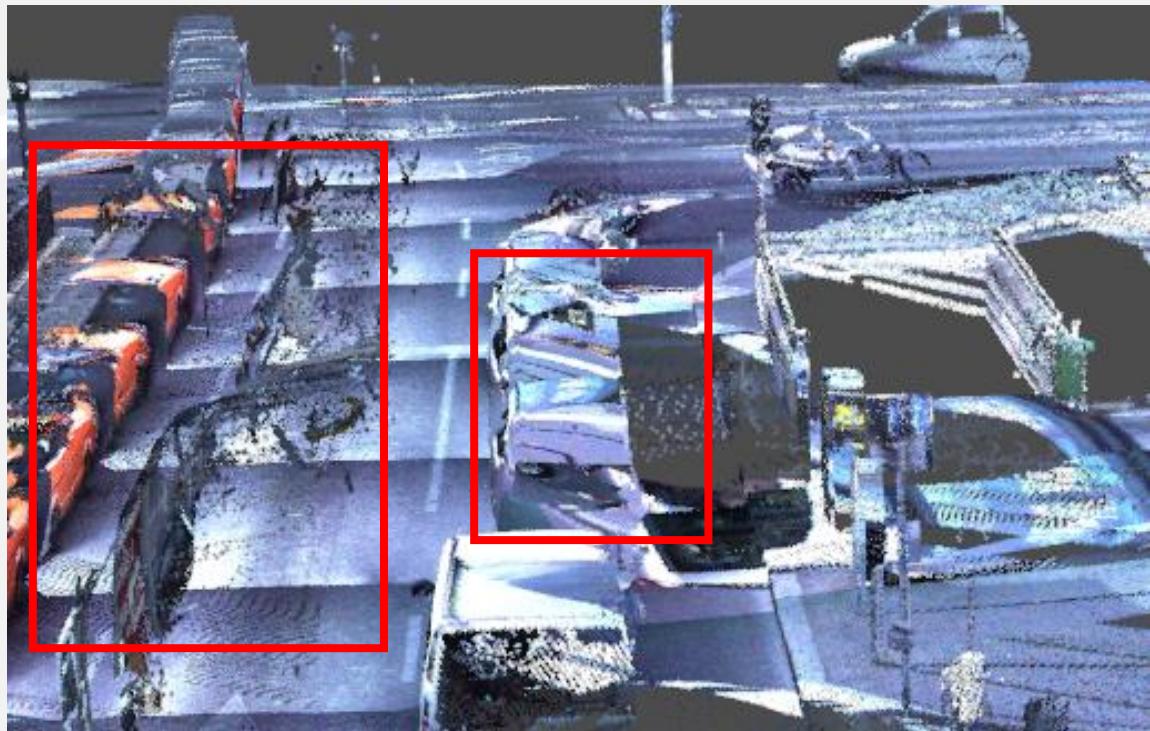
- Transfer learning from the camera-based „Vitpose” approach

— Camera-based skeleton
— Livox-based skeleton

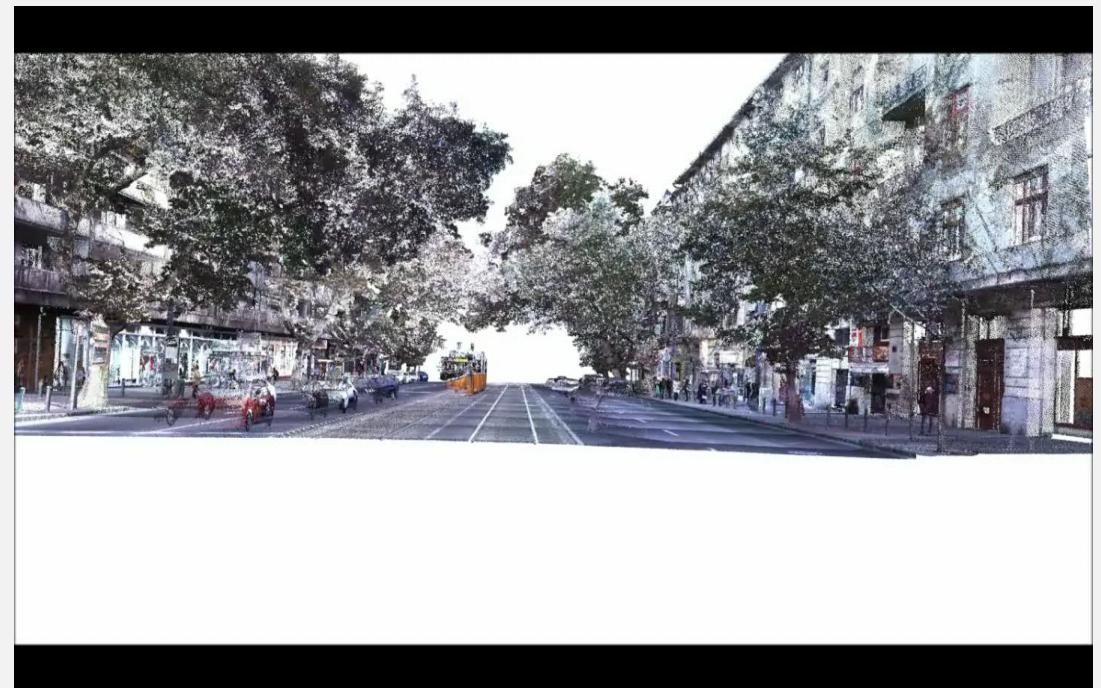


Publication: L. Kovács, B.M. Bódis and Cs. Benedek: "LidPose: Real-Time 3D Human Pose Estimation in Sparse Lidar Point Clouds with Non-Repetitive Circular Scanning Pattern," *Sensors*, vol. 25, no. 11, article 3427, 2024

Phantom object effects by mobile laser scanning

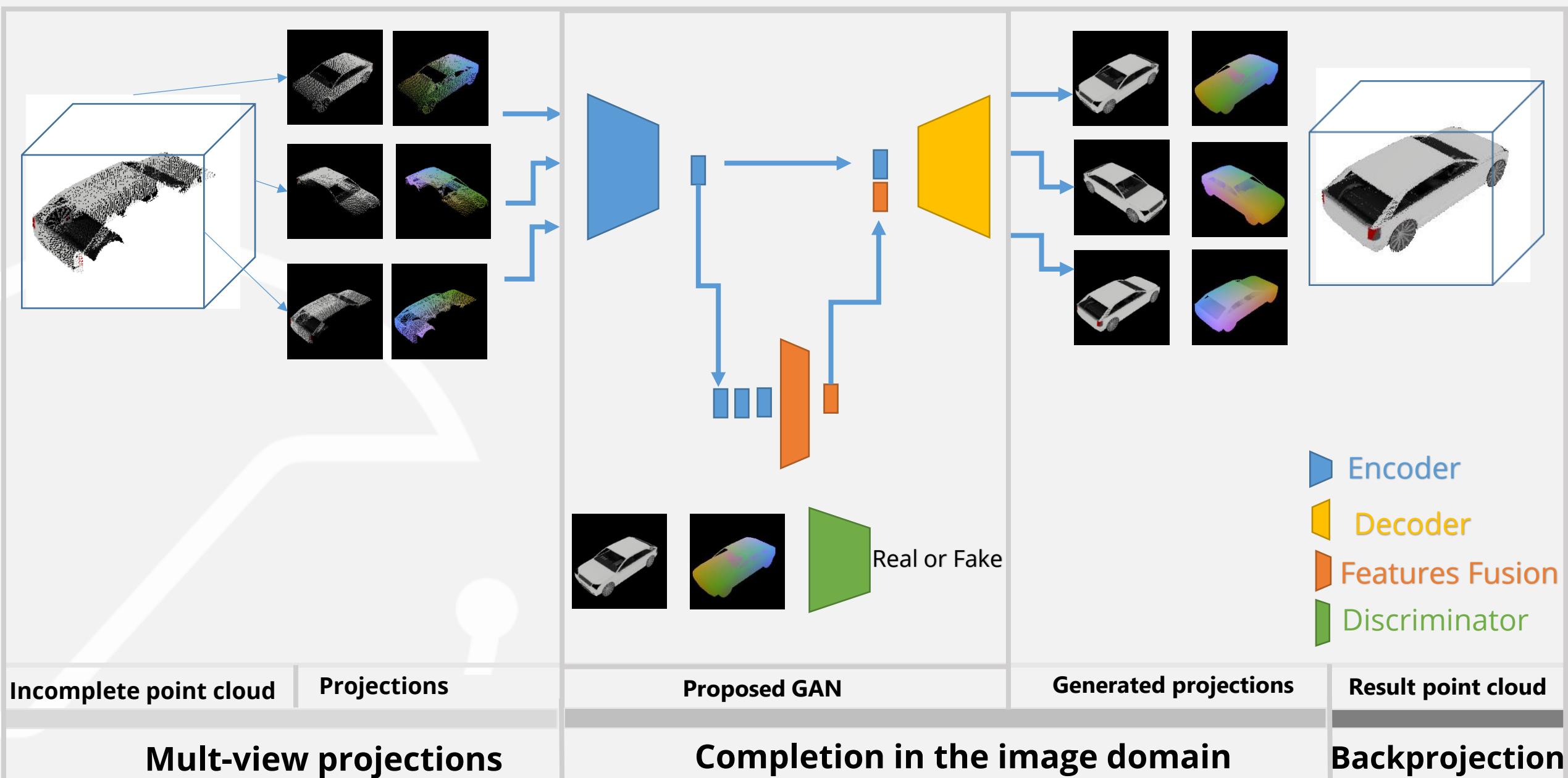


RIEGL VMX-450

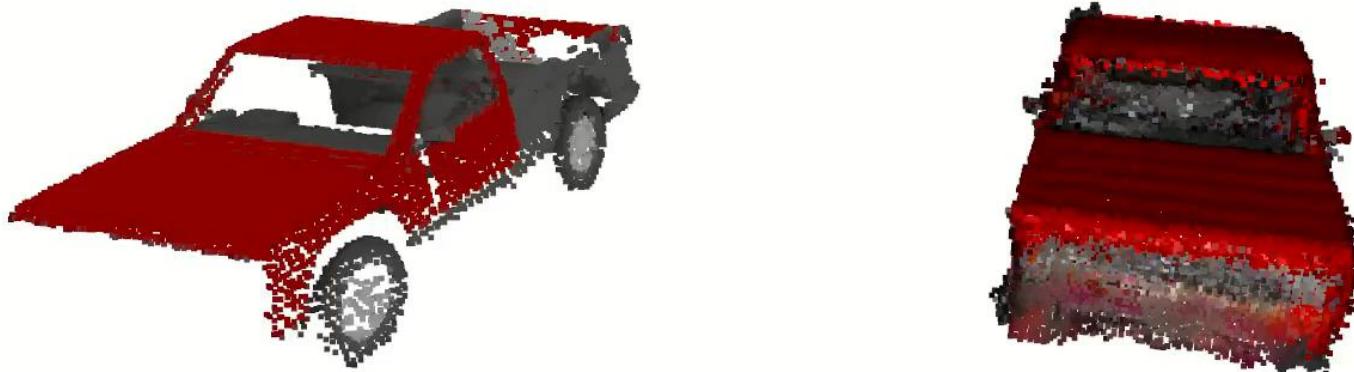


B. Nagy, and Cs. Benedek: "3D CNN Based Semantic Labeling Approach for Mobile Laser Scanning Data", *IEEE Sensors Journal*, vol. 19, no. 21, pp. 10034 – 10045, 2019

Point cloud completion in 3D



Point cloud completion in 3D



Publication: Y. Ibrahim and Cs. Benedek: "MVPCC-Net: Multi-View Based Point Cloud Completion Network for MLS Data," *Image and Vision Computing*, Elsevier, vol. 134, article 104675, 2023

Experiments with foot-powered mobile robots



Viewpoint of the robot dog



THANK YOU FOR YOUR ATTENTION!

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