Exploiting Indoor Mobile Laser Scanner Trajectories for Interpretation of Indoor Scenes

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Promoter: Prof. Dr. Ir. George Vosselman
Supervisor: Michael Peter

Indoor 3D Model Reconstruction to Support Disaster Management in Large Buildings

Smart Indoor Models in 3D (SIMs3D)

SIMs3D Project partners

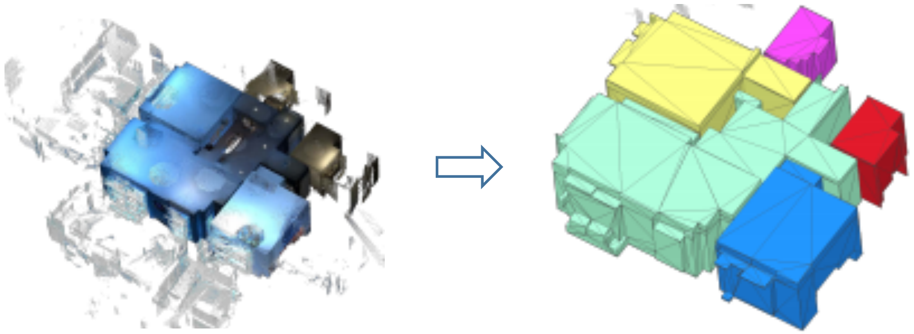
1. STW as a technology foundation
2. Academic partners:
   - University of Twente (UT), EOS Department
   - Delft University of Technology (TUD), GIS Technology
3. Companies:
   - Cyclomedia Technology B.V.
   - Leap3D
   - CGI Nederland B.V. as a software advisor
4. End Users:
   - iNowit Brandweer Nederland as an end user and advisor for user cases
   - Open Geospatial Consortium (OGC) as the user of the final IndoorGML

Indoor 3D Model Reconstruction to Support Disaster Management in Large Buildings

Smart Indoor Models in 3D (SIMs3D)

SIMs3D Project Goals

1. Indoor 3D reconstruction from point clouds (UT)
2. Emergency responses in public buildings (TUD)



Point clouds 3D model

Ikehata et al. 2015

Data:

Mobile Laser Scanner (MLS) point cloud

Terrestrial Laser Scanner (TLS)

Images

Microsoft Kinect

ZebRevo

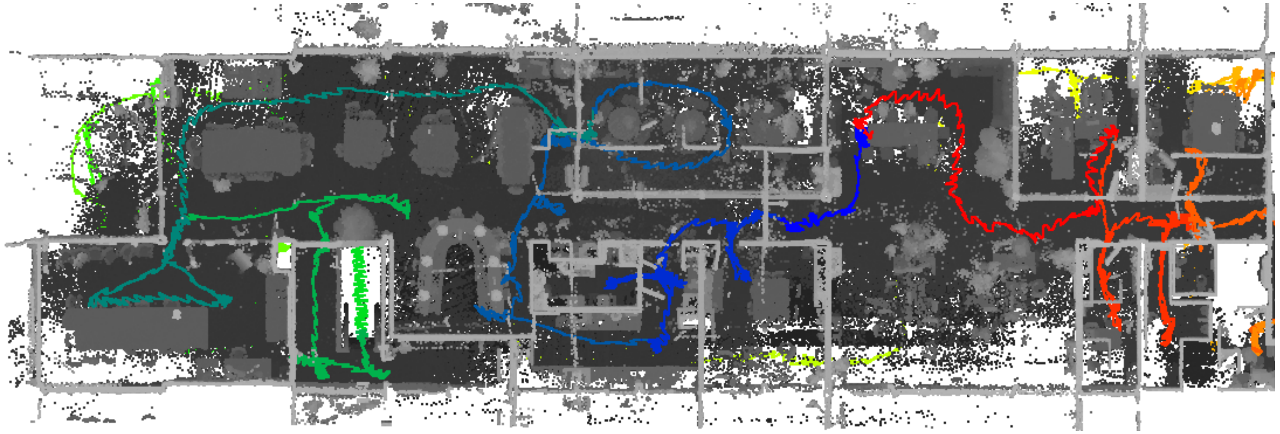
Our backpack system

NavVis M3 Trolley

Problem and Motivation:

- Permanent structure reconstruction, wall detection
- Room segmentation
- Opening detection from cluttered data: door, window
- Reflection from the glass surfaces

Zeb1



trajectory

Problem and Motivation:

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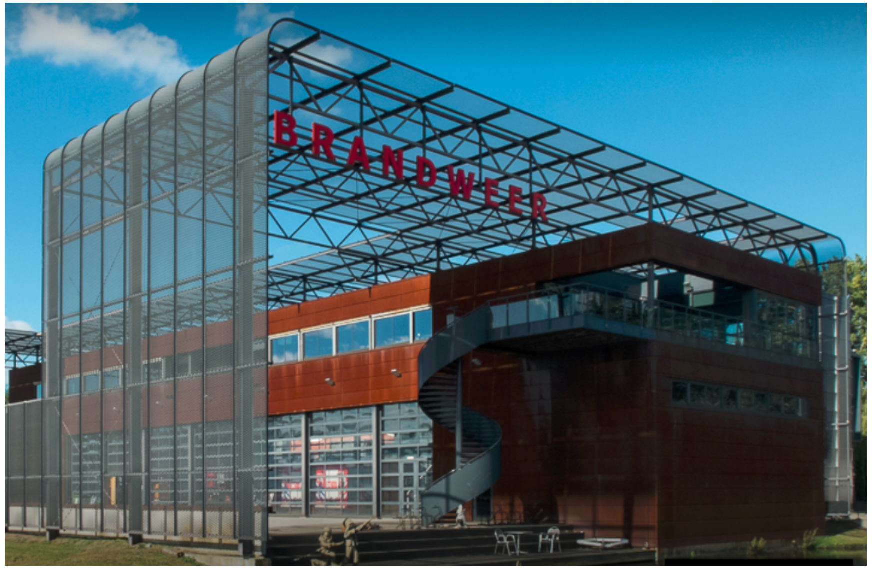
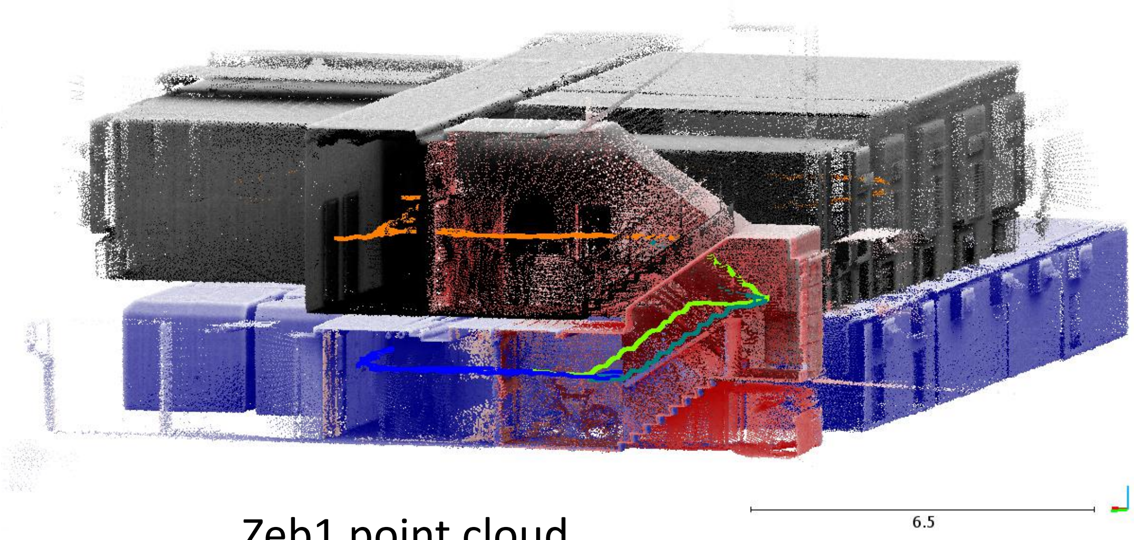
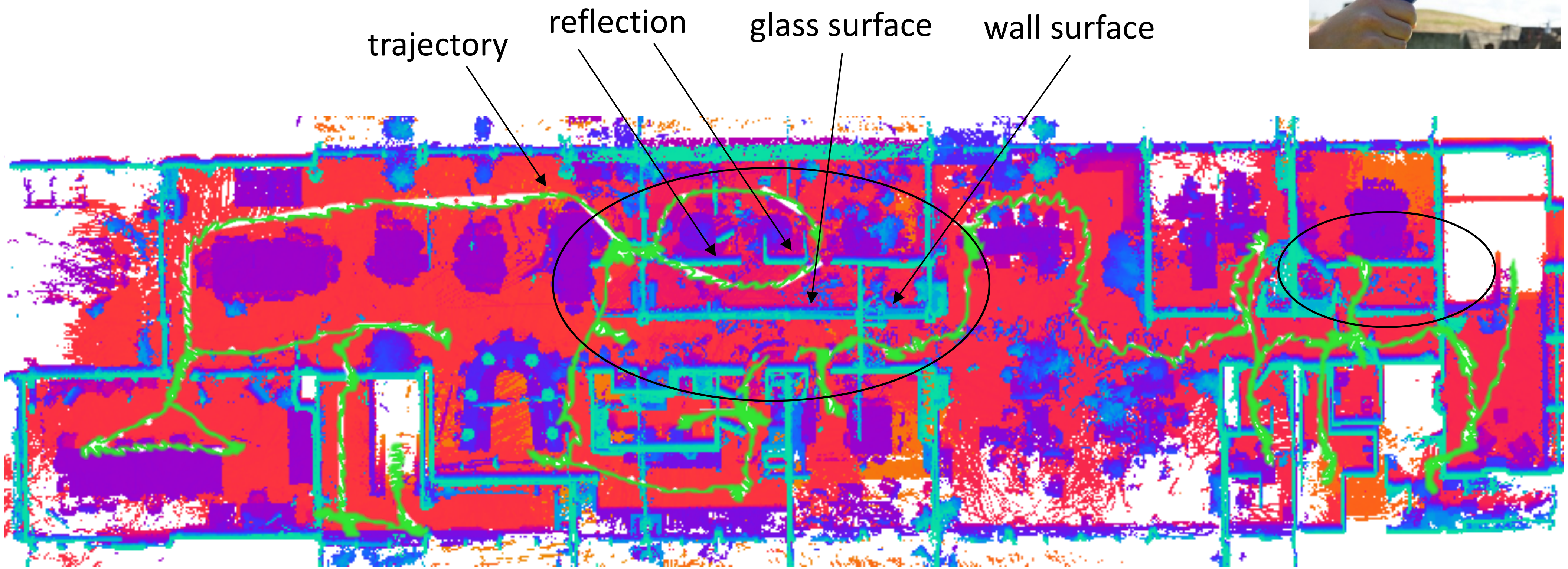




Zeb1 point cloud
source: A. Elseicy thesis

Zeb1

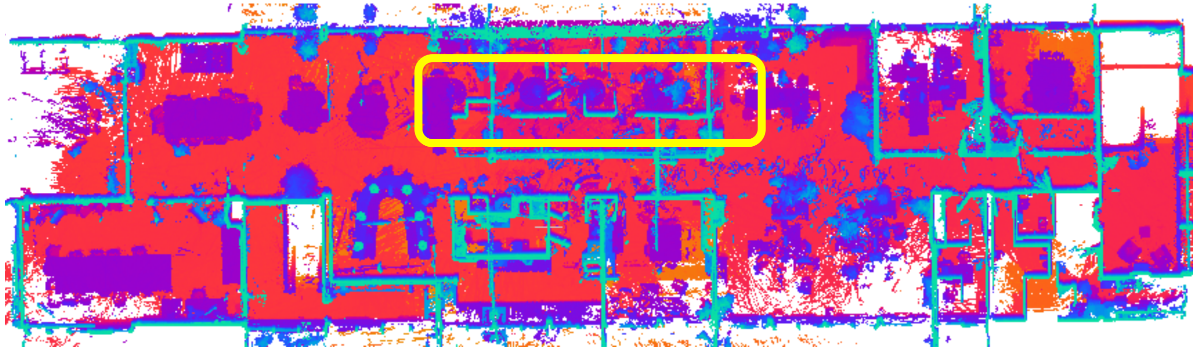
Removing reflected points because of glass surfaces:

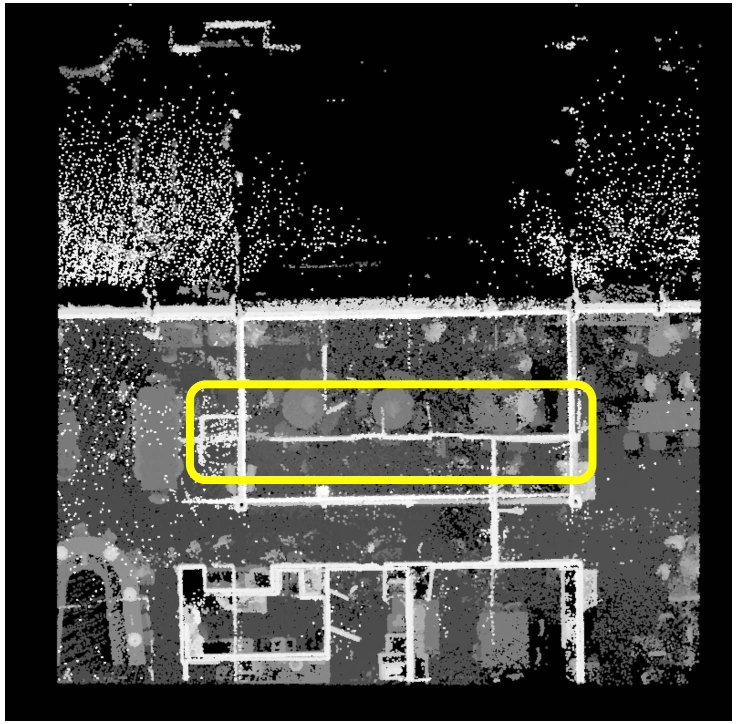


Top view of a room containing reflected surfaces.

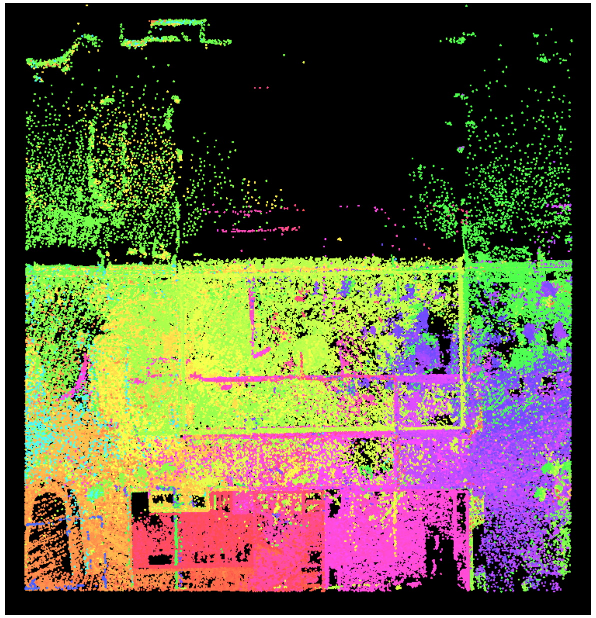
Points are colored by height.

Removing reflected points because of glass surfaces:

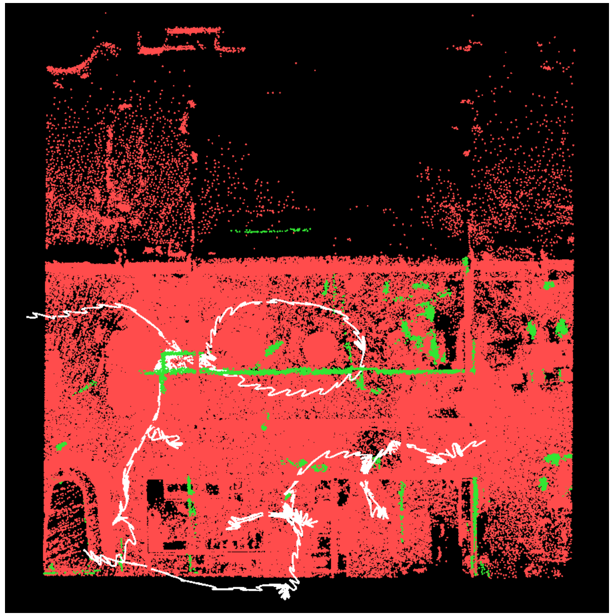




Top view of a room with reflected surfaces, yellow area.



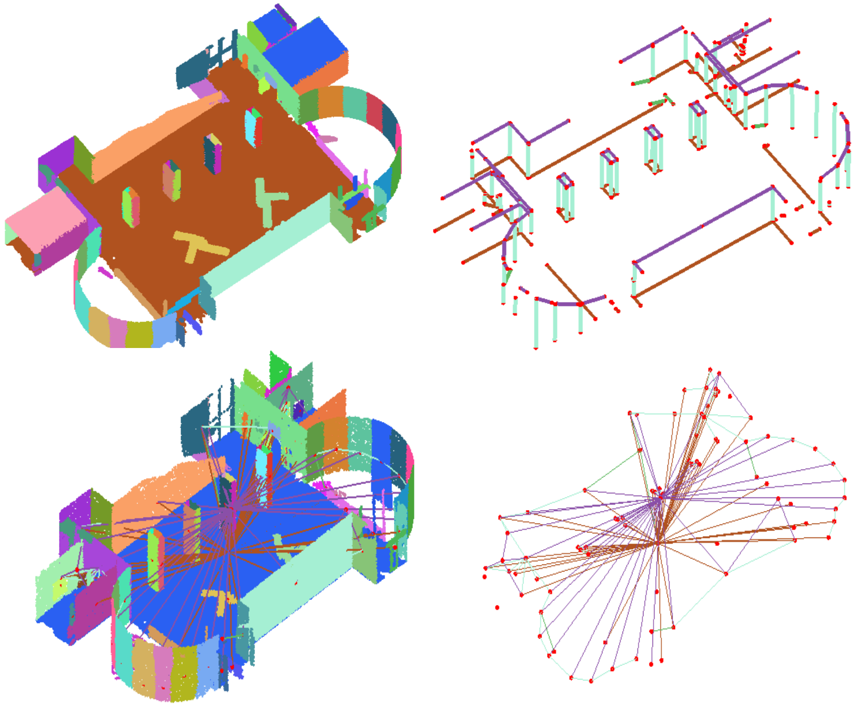
Top view of the same area, colored by time.

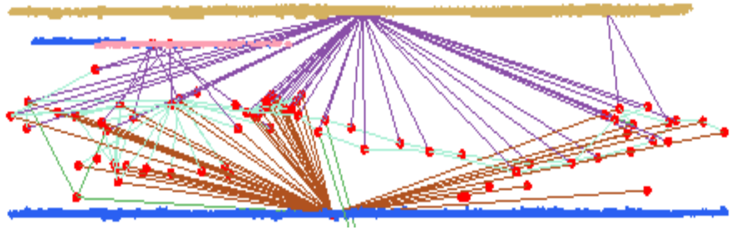


Top view. Reflected segments are green.

Wall detection:

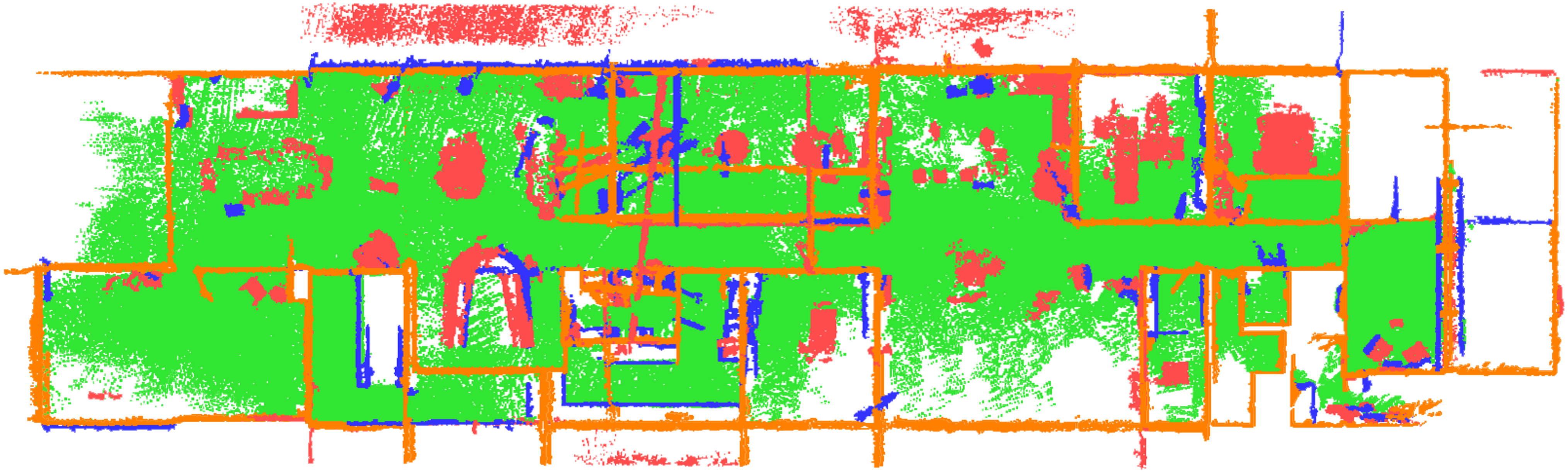
- Generate wall patches
- Intersect segments
- Generate an adjacency graph
- Label graph edges as:
  wall-wall, wall-ceiling, wall-floor
- Label graph nodes based on
  number of edges' labels





Side view of the graph

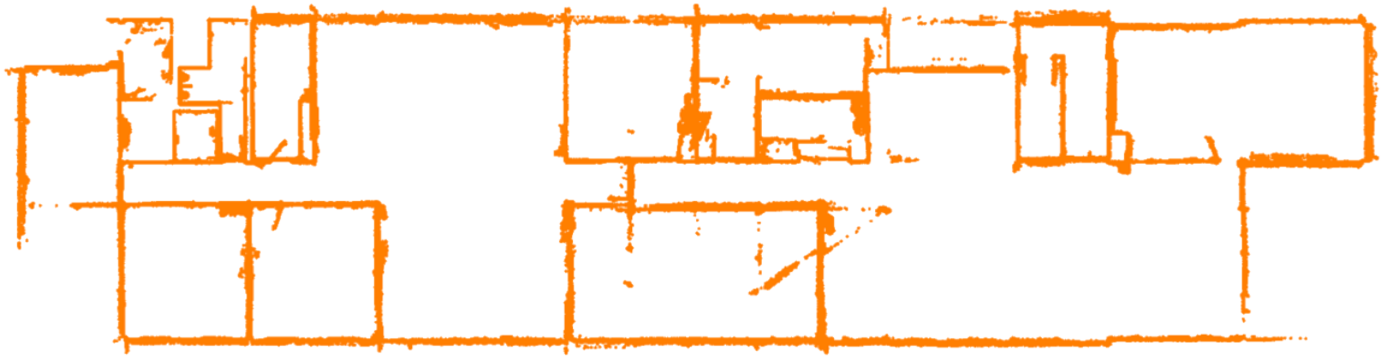
Wall detection result:



Zeb1 data from Fire brigade building (top view)

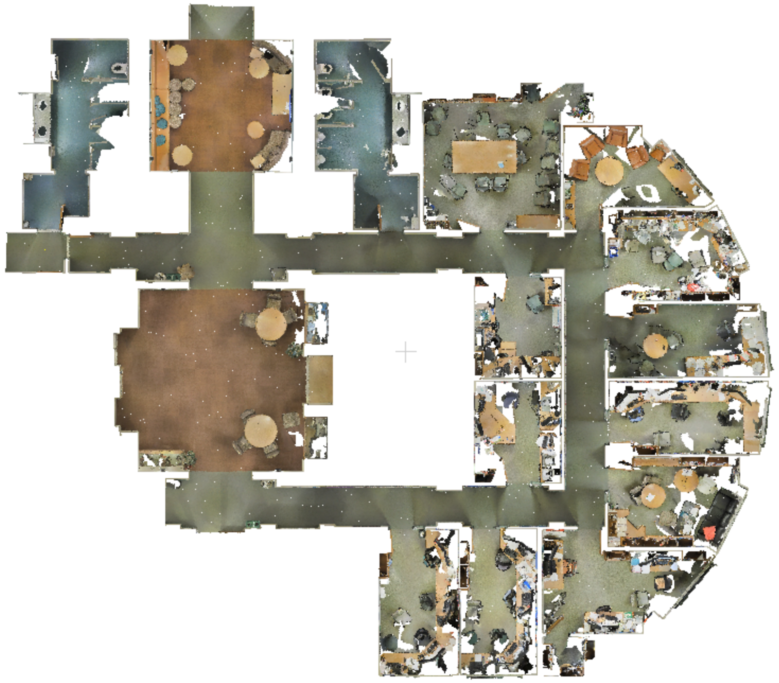
Wall detection result:

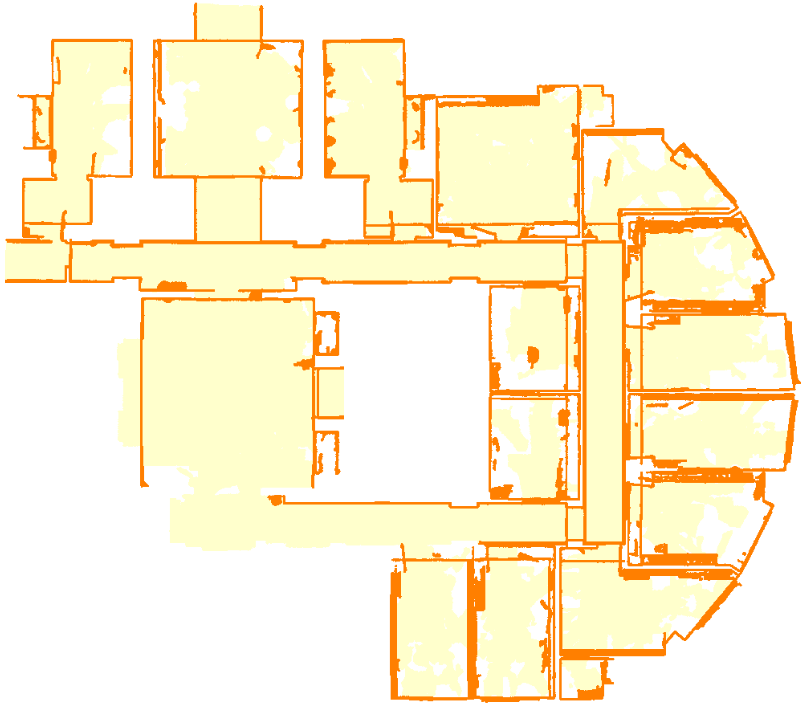
Detected walls from 1st iteration (top view)



Detected walls from 2nd iteration (top view)

Wall detection result:

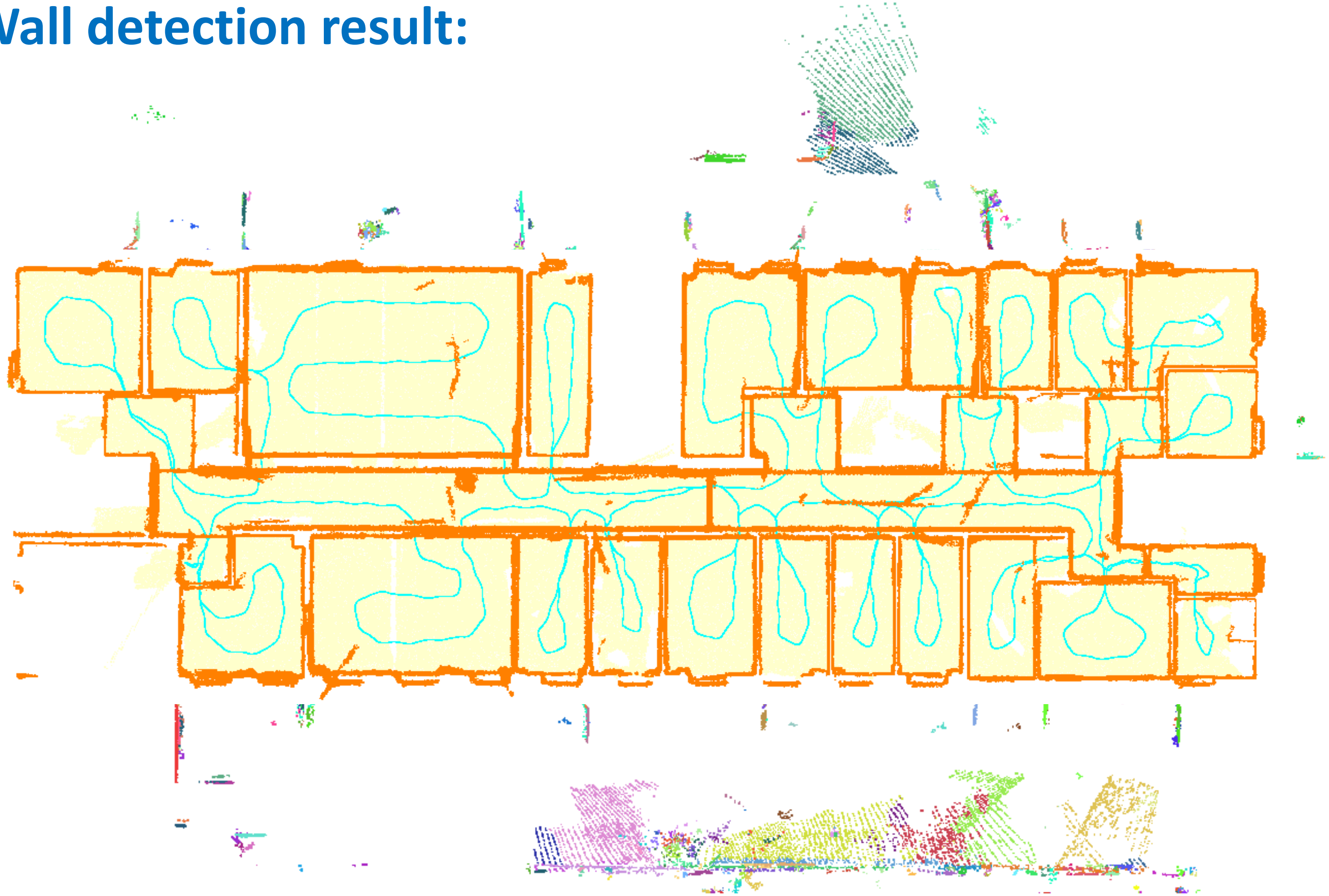




Matterport system

Matterport data from Stanford
Compared with ground truth (top view)
noise: 1 cm, 2 mil points

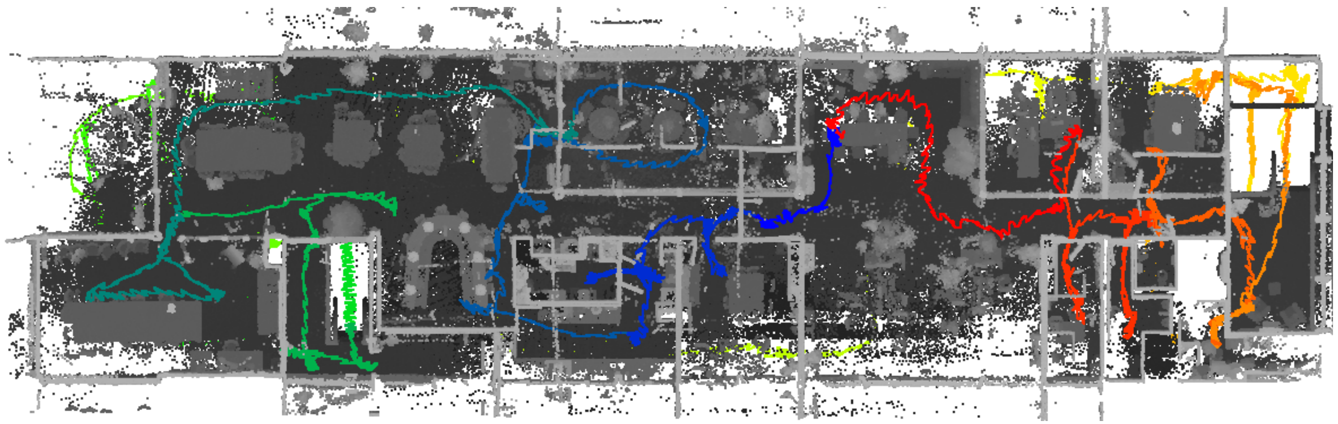
Wall detection result:



Our Backpack System Data

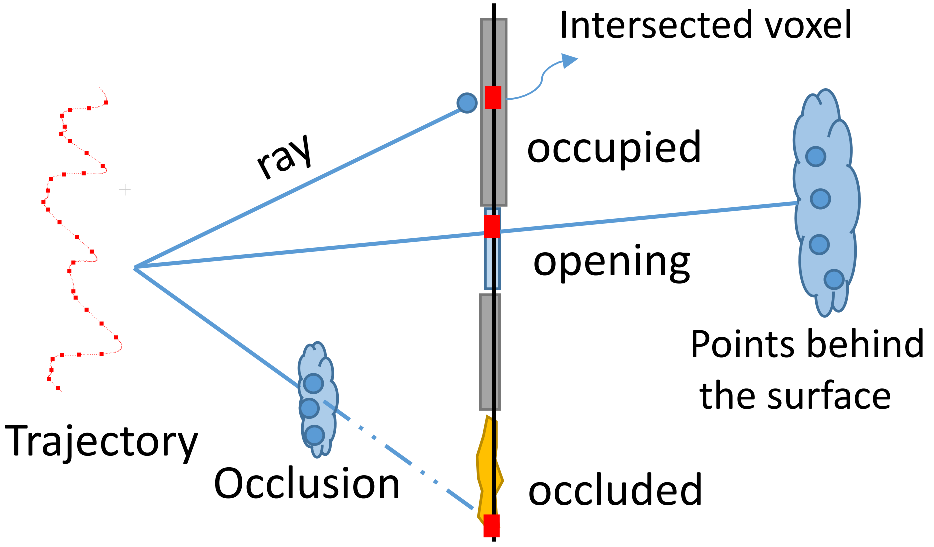
Opening detection: Opening detection using occlusion test

- Point clouds from Zeb1
- MLS trajectory as sensor position



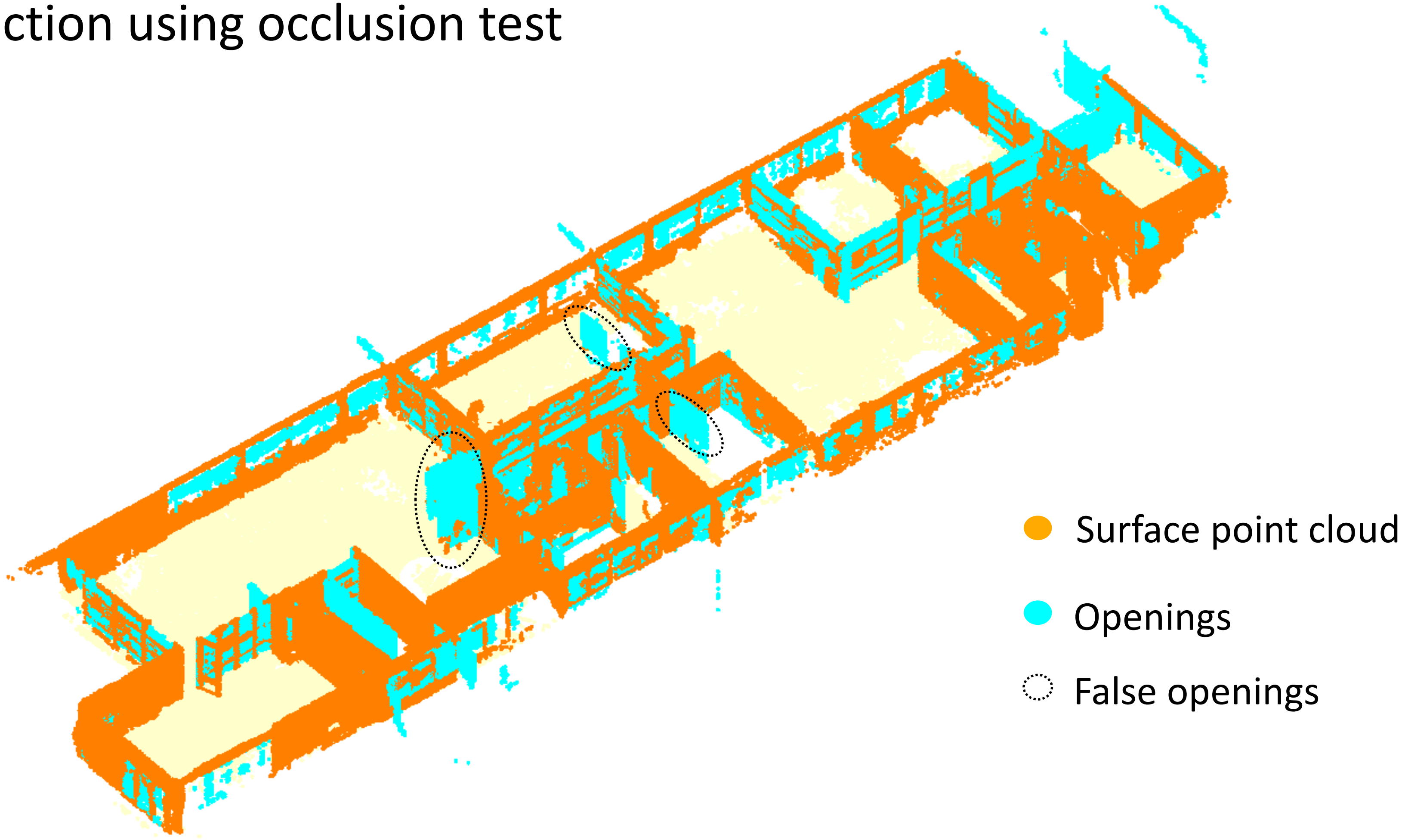
Zeb1 data from Fire brigade building (top view)

Wall Plane (right side view)

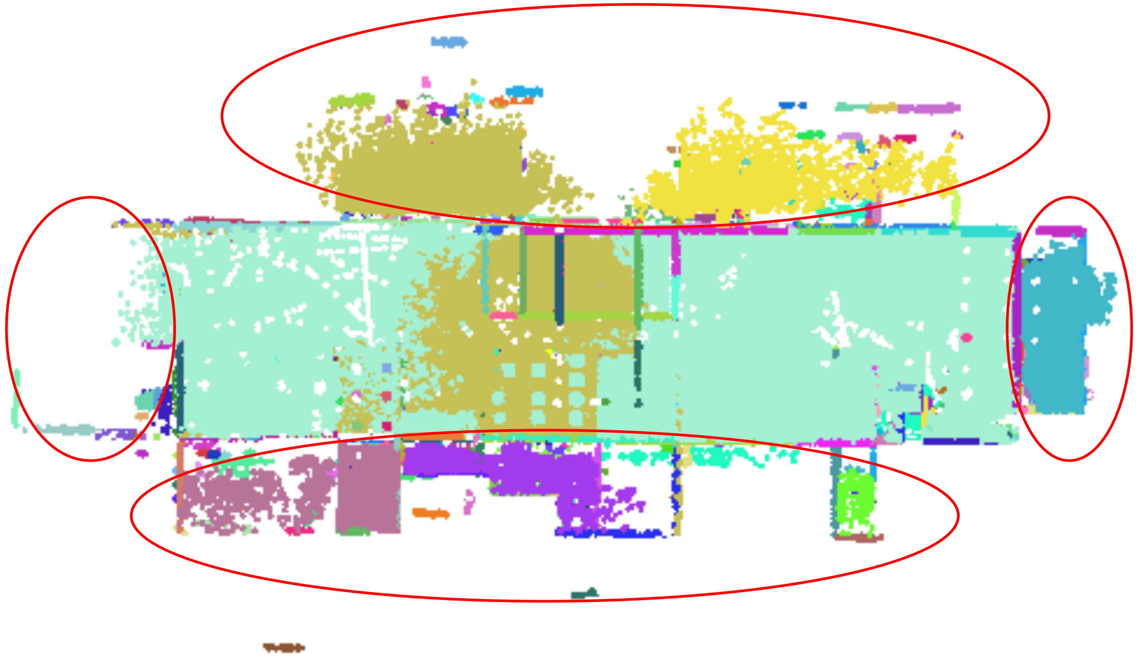


Opening detection :

Opening detection using occlusion test



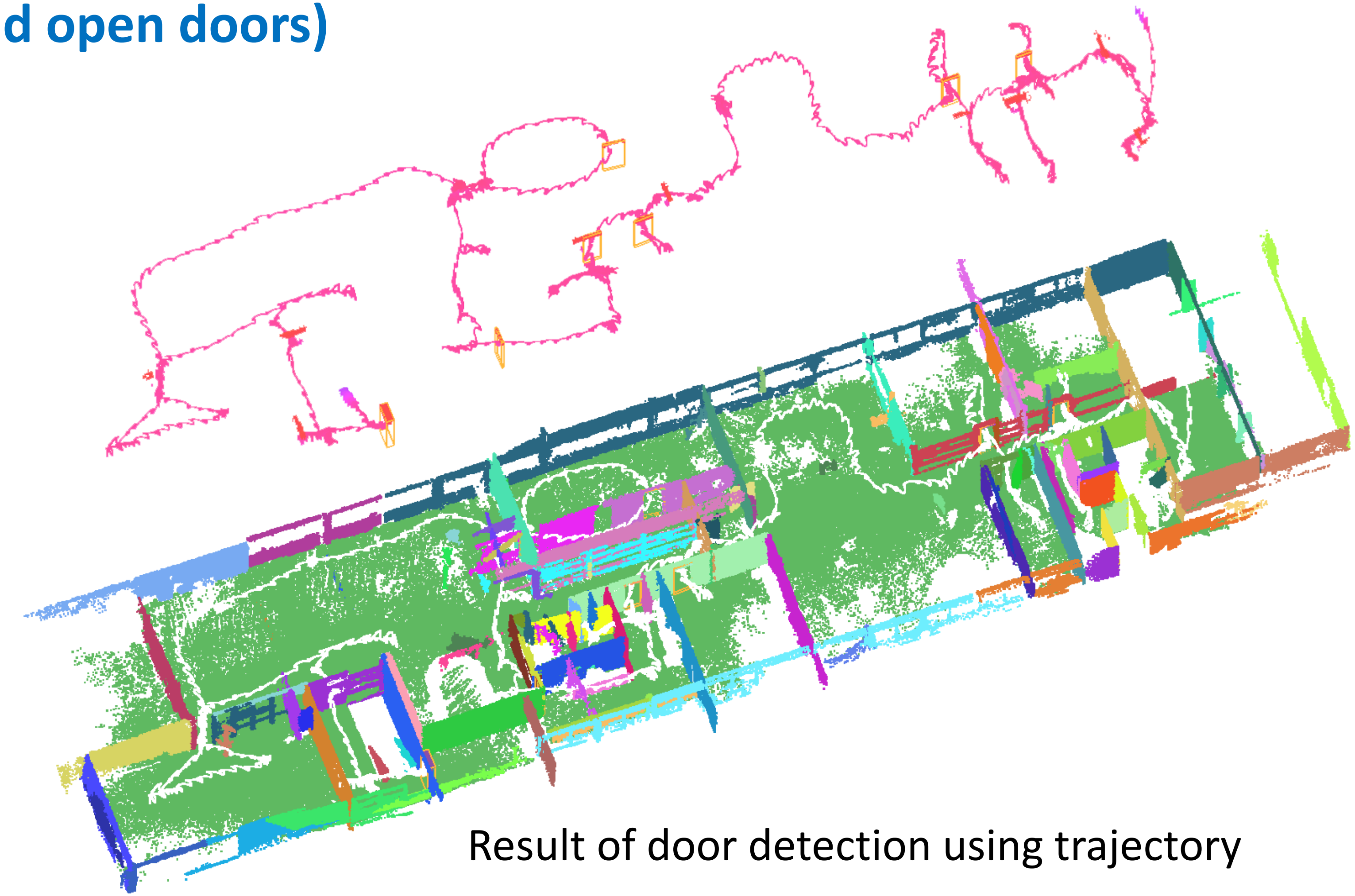
Opening detection : modified laser points



Original laser points

Modified laser points by removing points behind the surfaces

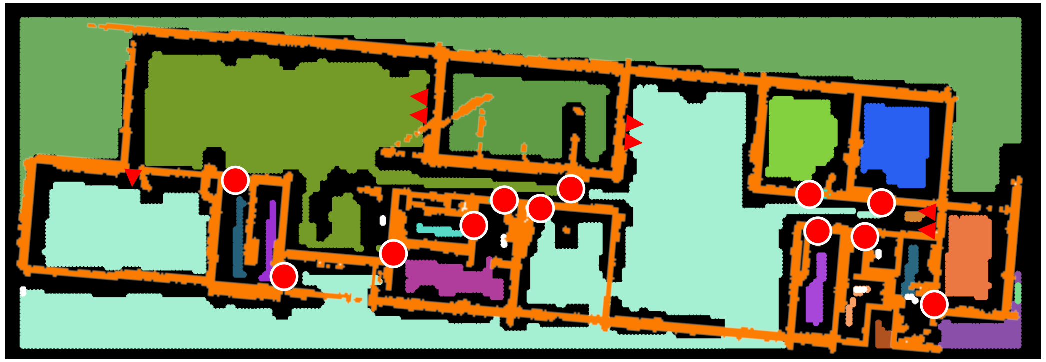
Door detection
(closed and open doors)



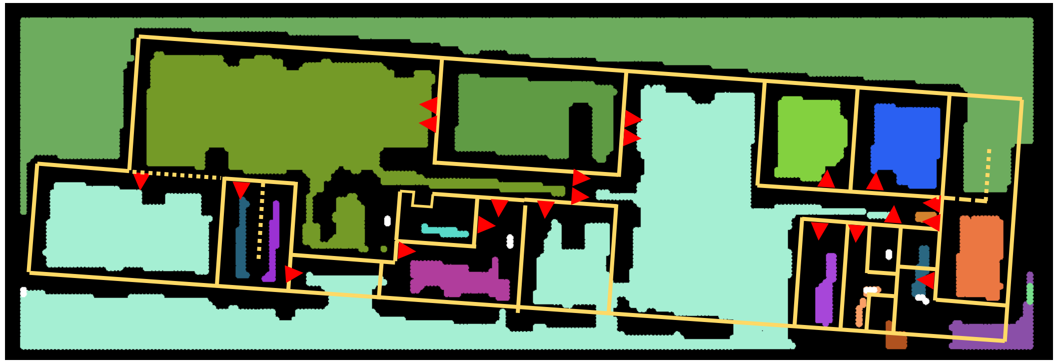
Result of door detection using trajectory

Space partitioning and navigable space using voxels

Space partitions



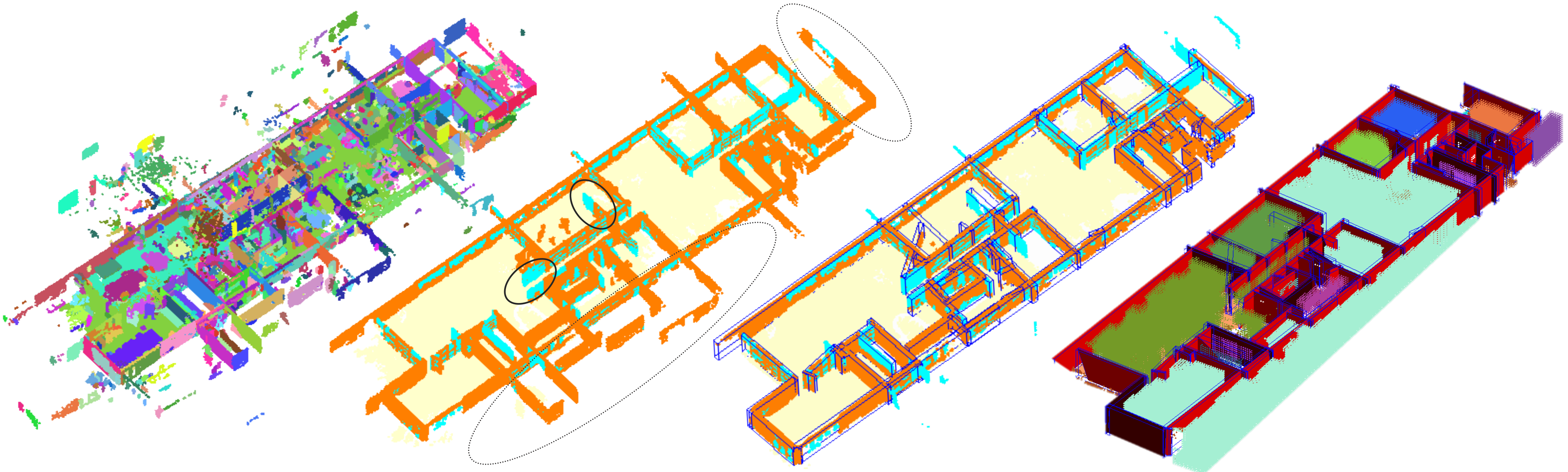
Space partitions, walls and doors



Space partitions and ground truth walls

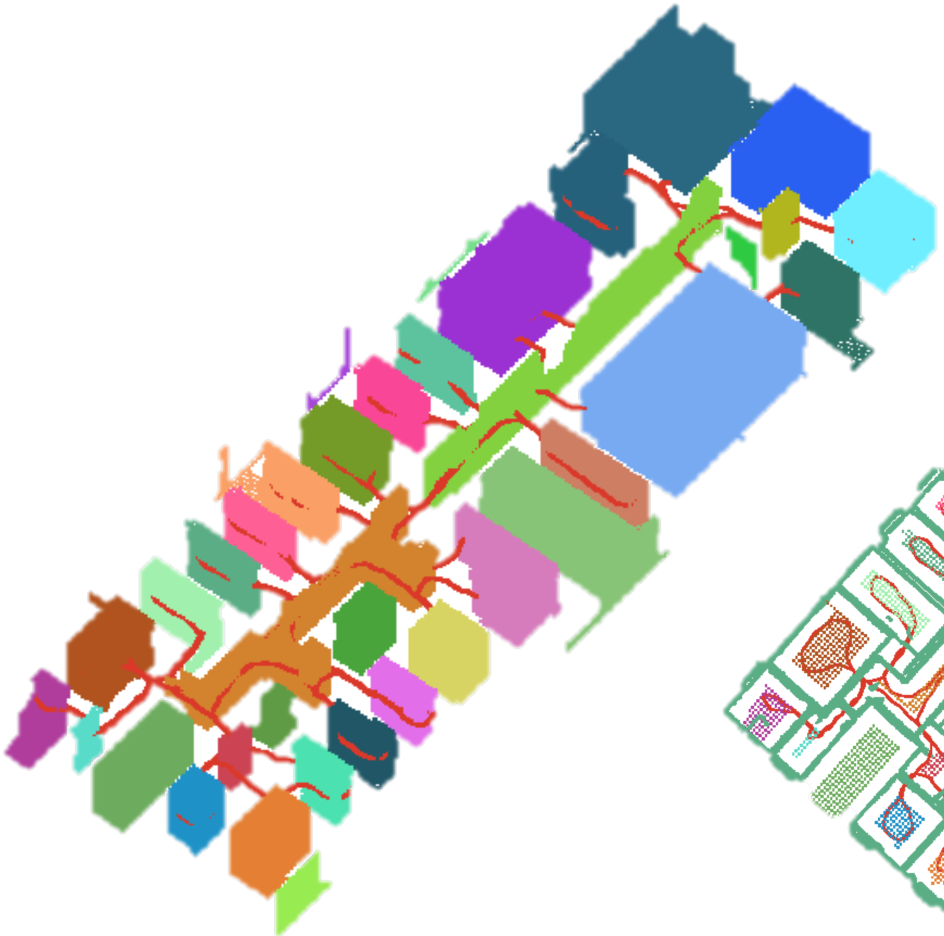
Space partitions and navigable space

All results together

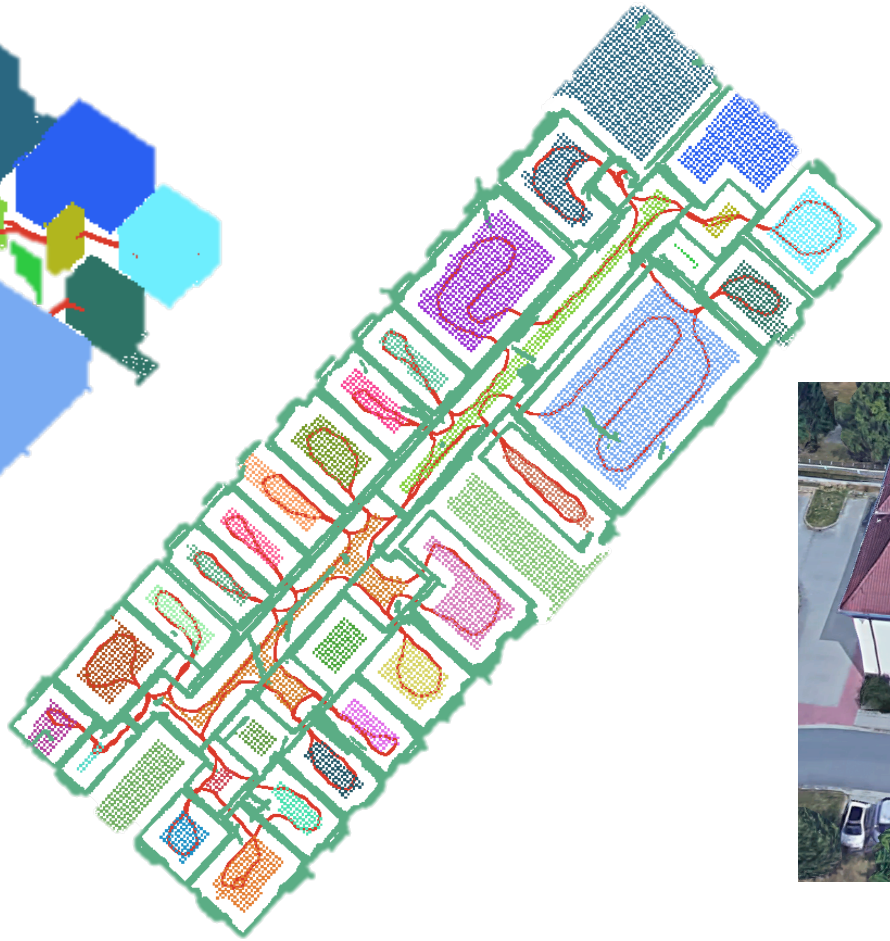


Point clouds Openings (cyan color) Wall Boxes Space Partitions

Backpack system data



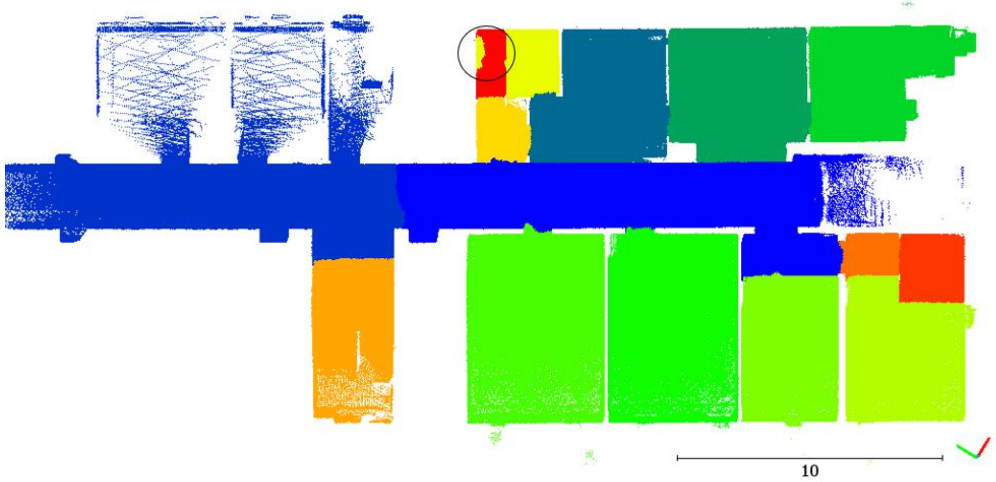
Space Partitions and trajectory

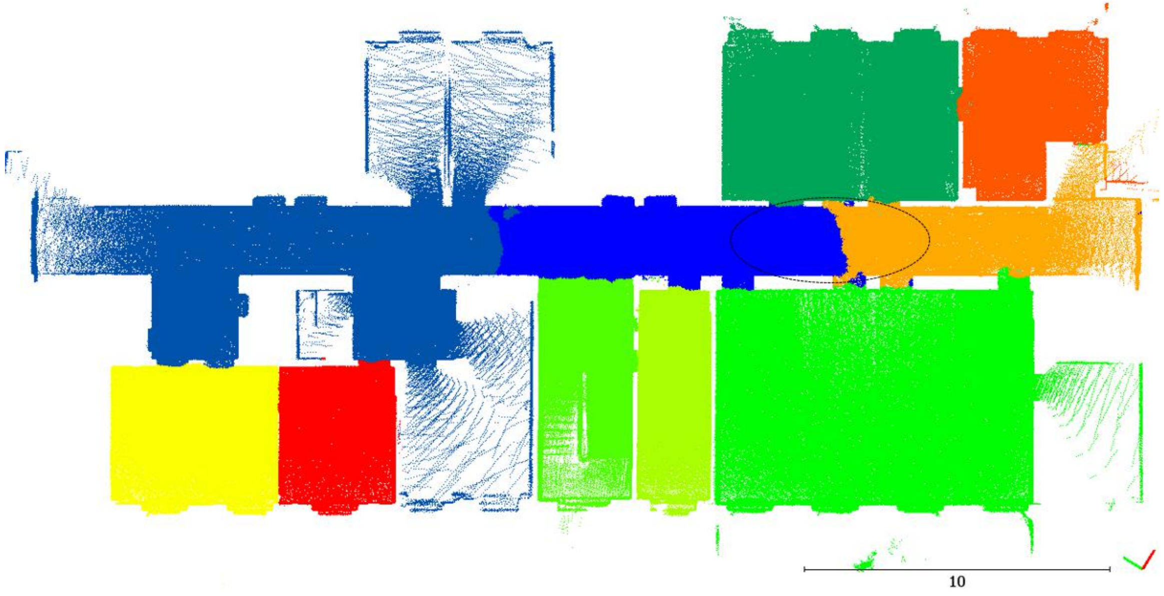


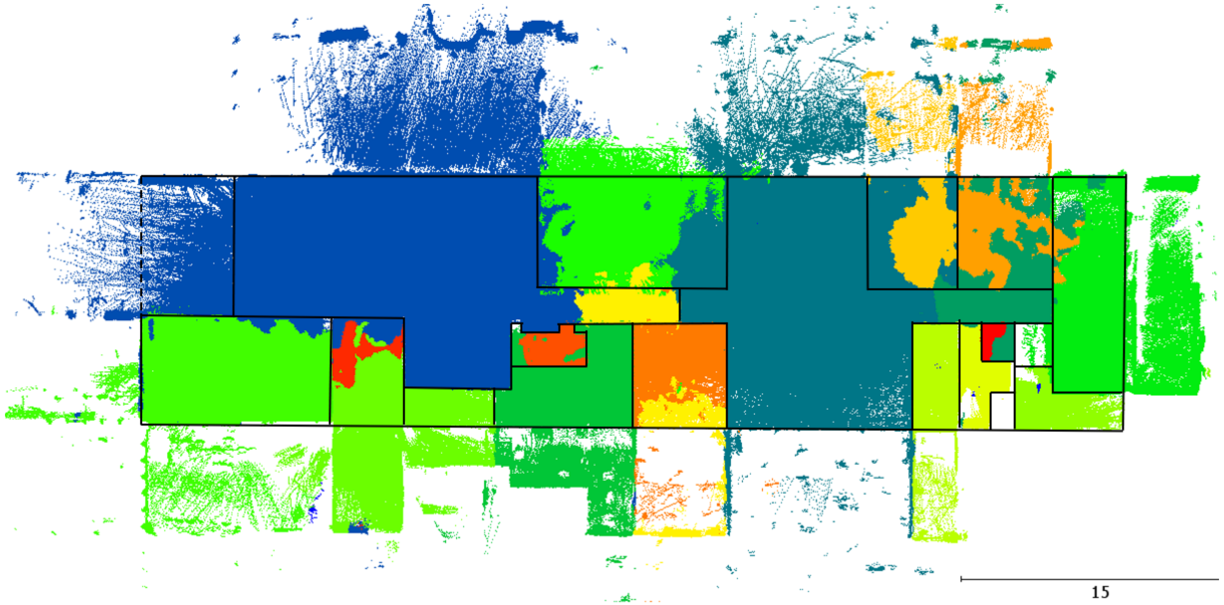
Navigable space and walls

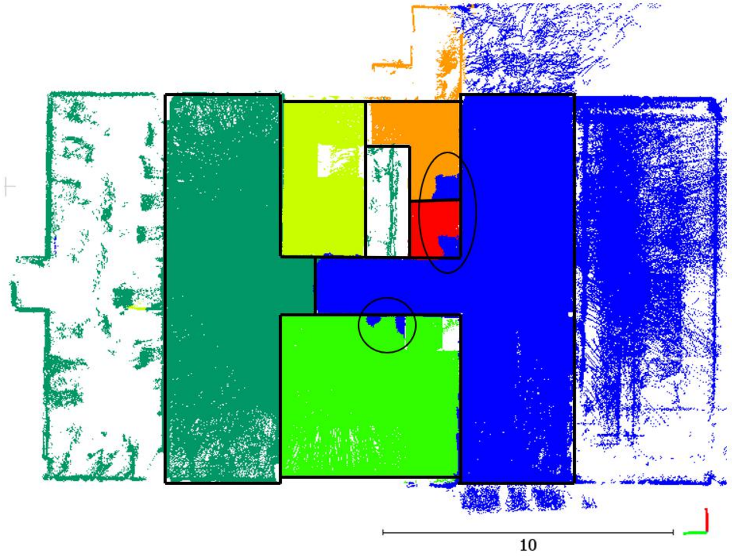
Diemen Building in Braunschweig

Room Segmentation









source: A. Elseicy’s Msc Thesis

Exploiting MLS Trajectory for Interpretation of Indoor laser Scanner Data

More details:

In The ISPRS GeoSpatial Week 2017, Wuhan, China

Exploiting Indoor Mobile Laser Scanner Trajectories for Semantic Interpretation of Point Clouds

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Commission IV, WG IV/5

KEY WORDS: Indoor Point Clouds, MLS Trajectory, Indoor Reconstruction, Opening Detection, Occlusion Reasoning, 3D Model

ABSTRACT:

The use of Indoor Mobile Laser Scanners (IMLS) for data collection in indoor environments has been increasing in the recent years. These systems, unlike Terrestrial Laser Scanners (TLS), collect data along a trajectory instead of at discrete scanner positions. In this research, we propose several methods to exploit the trajectories of IMLS systems for the interpretation of point clouds. By means of occlusion reasoning and use of trajectory as a set of scanner positions, we are capable of detecting openings in cluttered indoor environments. In order to provide information about both the partitioning of the space and the navigable space, we use the voxel concept for point clouds. Furthermore, to reconstruct walls, floor and ceiling we exploit the indoor topology and plane primitives. The results show that the trajectory is a valuable source of data for feature detection and understanding of indoor MLS point clouds.

1. INTRODUCTION

Indoor 3D models are required for navigation, building maintenance, disaster management and many other applications. However, manual creation of indoor 3D models is an expensive and cumbersome process for large buildings such as airports,

reconstruction methods are often limited to Manhattan-World structure (Budroni and Boehm, 2010) or employ horizontal floor/ceiling and vertical wall assumption (Ochmann et al., 2016; Oesau et al., 2014; Xiao and Furukawa, 2014). Other methods generate 2.5D models (Oesau et al., 2014; Turner and Zakhor, 2014) or do not consider the detection of openings and addition of semantics (Mura et al., 2014a; Oesau et al., 2014; Xiao and

Thank you for your attention

Questions?

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Linkedin

Parameters:

Algorithm	Parameters	Value
Surface Growing Segmentation	distance to surface seed search radius	0.10 m 1.0 m
Reflection Removal	time difference # of reflected points in a segment	150 s 70%
Surface Patch Generation	planes distance segments distance planes angle	0.60 m 0.40 m 10 degree
Wall/Floor/Ceiling Detection	intersection threshold surface angle threshold floor height estimation (optional) ceiling height estimation (optional) dist to floor, ceiling (optional)	0.10 m 20 degree - - 0.50 m
Prune Wall Detection	dist to floor, ceiling	0.50 m
Occlusion Test (Opening detection)	voxel size closenees dist to surface	0.10 m 0.60 m
Space Partitioning	voxel size search windows size	0.10 m 5*voxel_size
Door Detection	voxel size door size (width, height) search windows size percentage of void_hood points trajectory search radius	0.10 9*21*voxel_size 5*voxel_size 70% 0.15 m

Class	Precision	Recall	F1-Score
Wall	0.88	0.95	0.91
Floor	0.93	0.98	0.95
Ceiling	0.93	0.98	0.95

Accuracy of results for wall, Floor and ceiling

Class	Precision
Openings	0.73
Occluded	0.57
Occupied	0.89

Accuracy of results for openings

Analyzing the methods:

- **Wall Detection:** relies on the segment generalization and connectivity of segments.
- **Opening Detection:** relies on the wall detection results, challenge in occluded openings and reflection from glass.
- **Door Detection:** relies on the trajectory and input door size parameter.
- **Space Partitioning:** windows and gaps in the data are problematic for space partitioning.

- **Advantages of our method:**

+ Applicable on non-Manhattan World
+ Applicable on non-vertical walls
+ Scalable to large datasets
+ Improvable with iterations

Disadvantages of our method:

- Big gaps in the data challenge adjacency graph
- Heavy clutter near the ceiling is problematic
- Each methods relies on previous results