

# Automatic Extraction of an IndoorGML Navigation Graph from an Indoor Point Cloud

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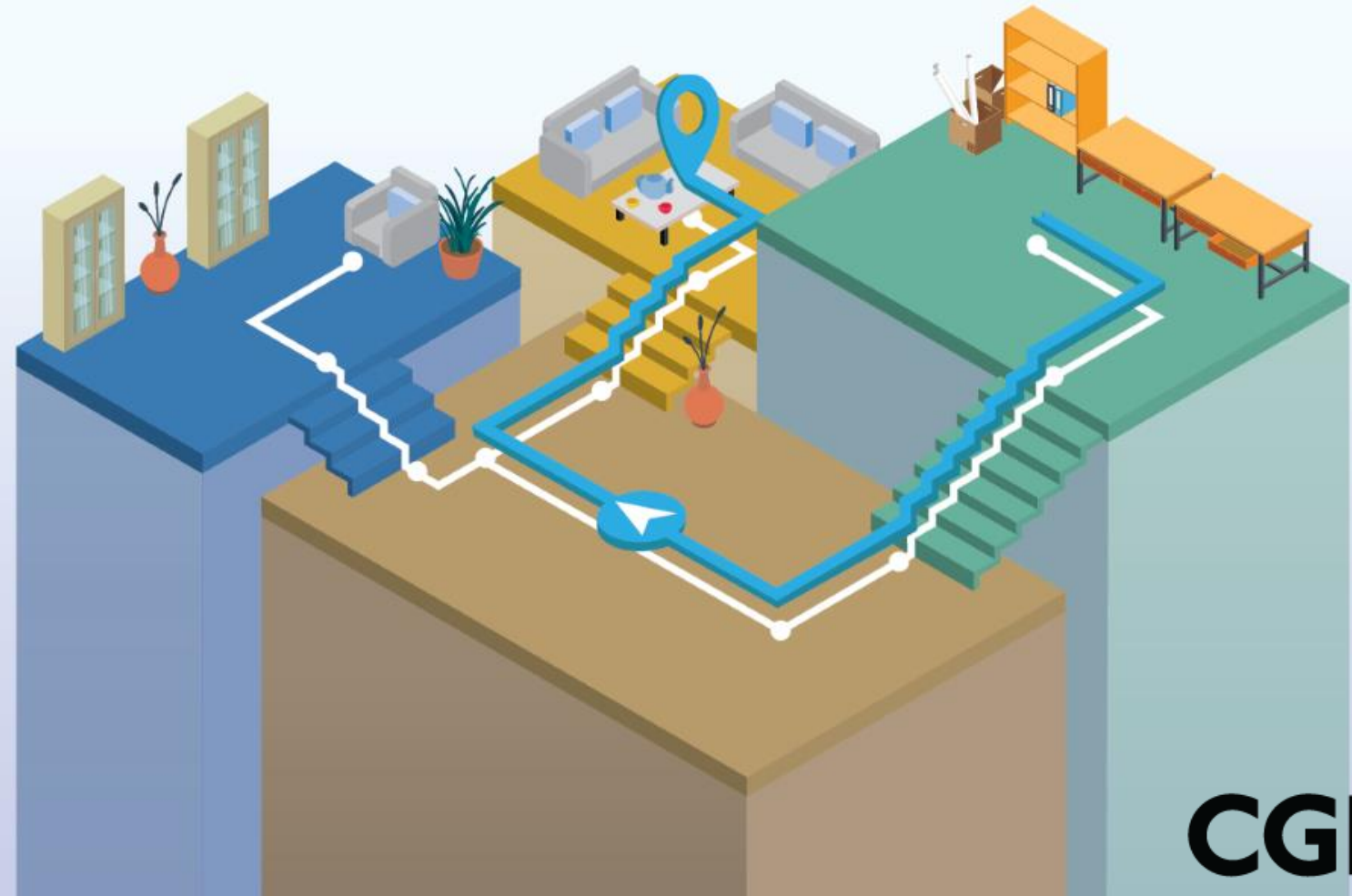
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*Delegate of BE*

*Frank van der Hoeven*



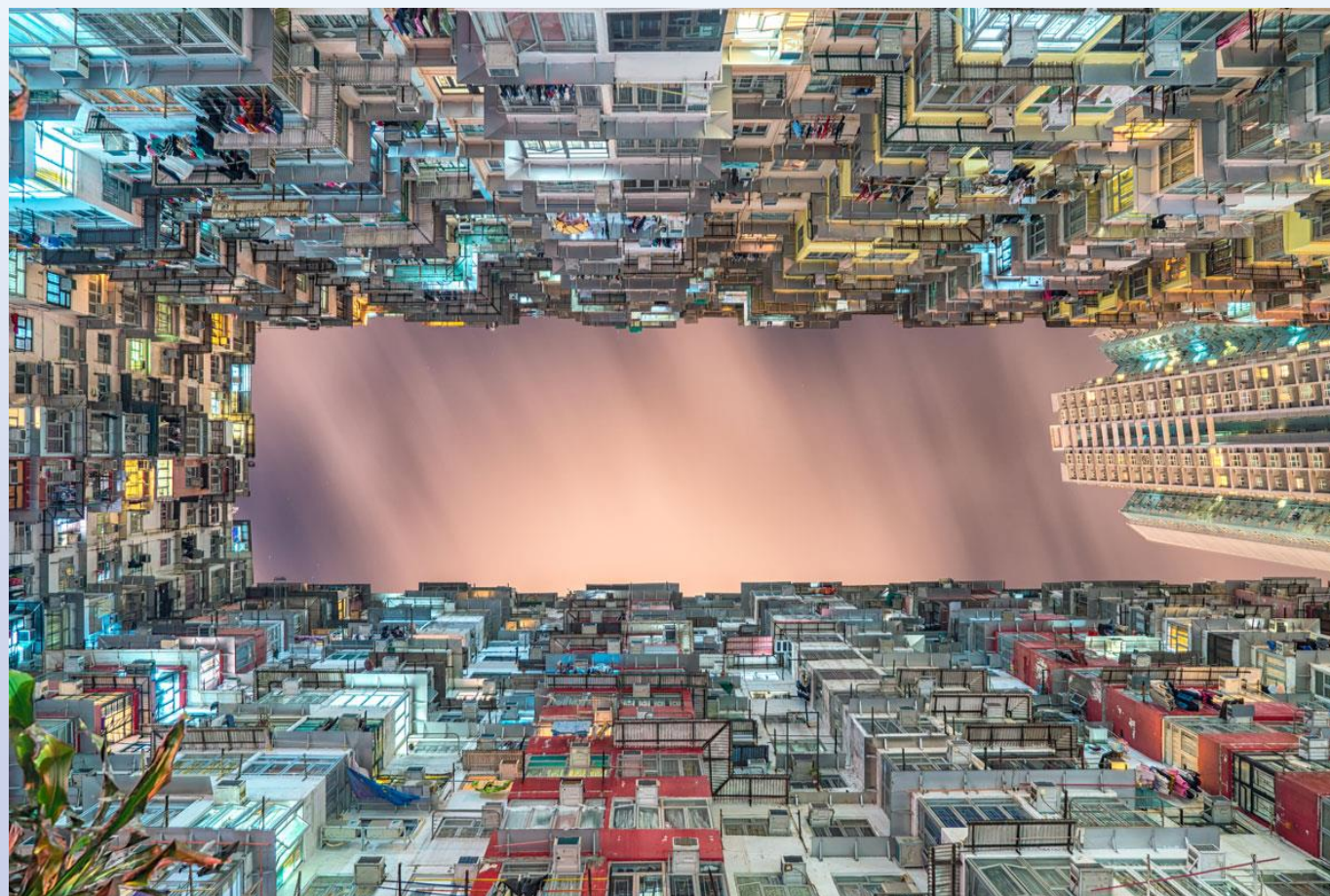
# Contents

- Motivation •
- Research objective •
  - Theory •
  - Methodology •
- Results & analysis •
  - Conclusions •

# Motivation

# Why indoor navigation?

- Urbanisation (more than 50% of people living in cities)



# Why indoor navigation?



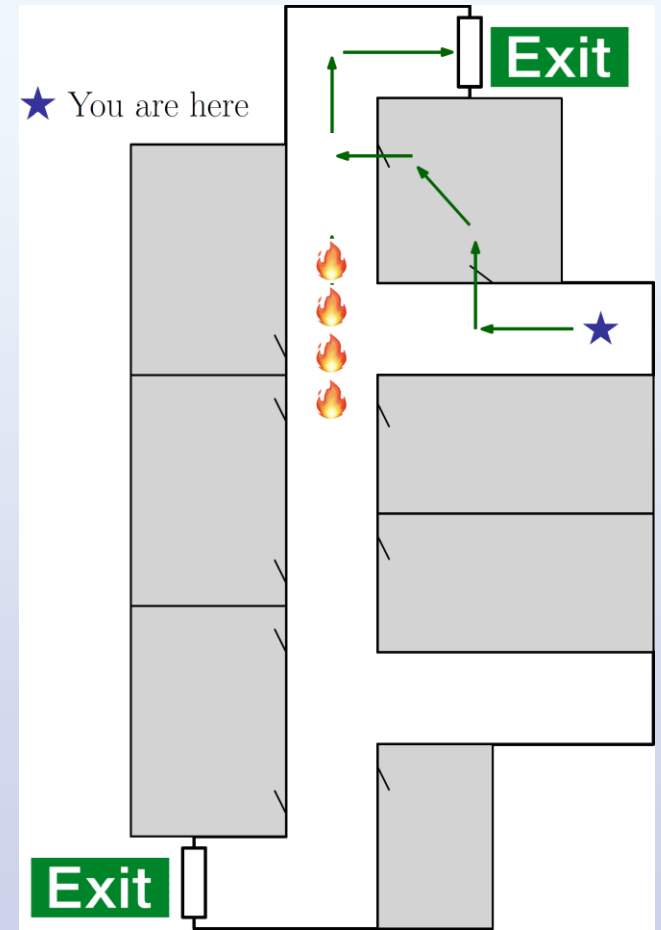
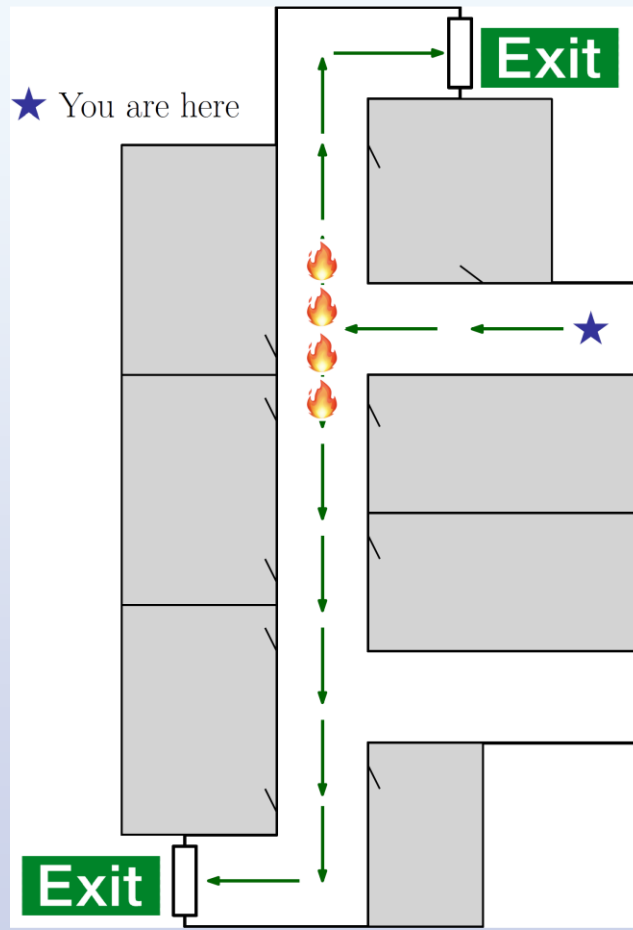
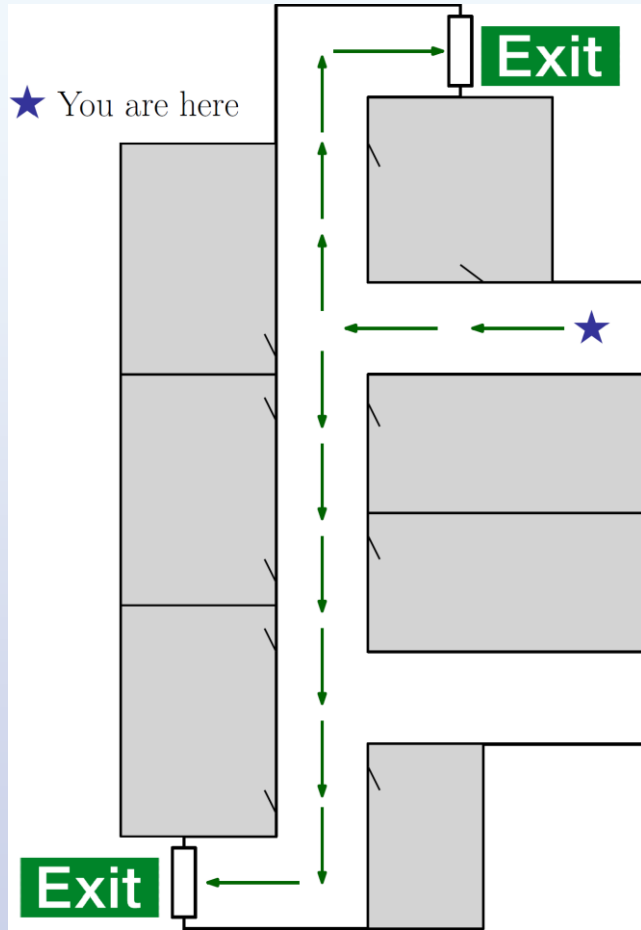
# Why indoor navigation?

- People with reduced mobility



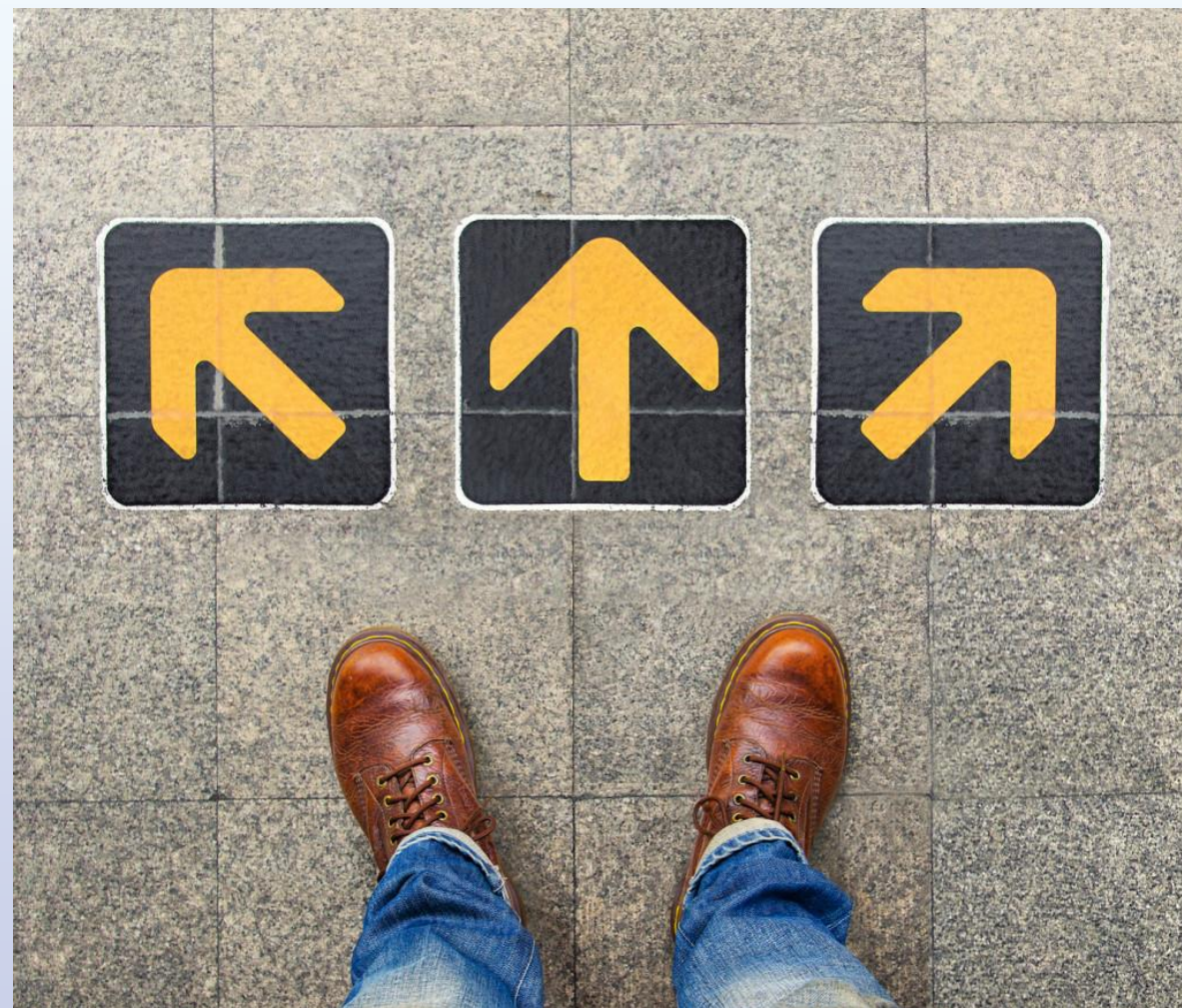


# Why indoor navigation?



# What is needed for indoor navigation?

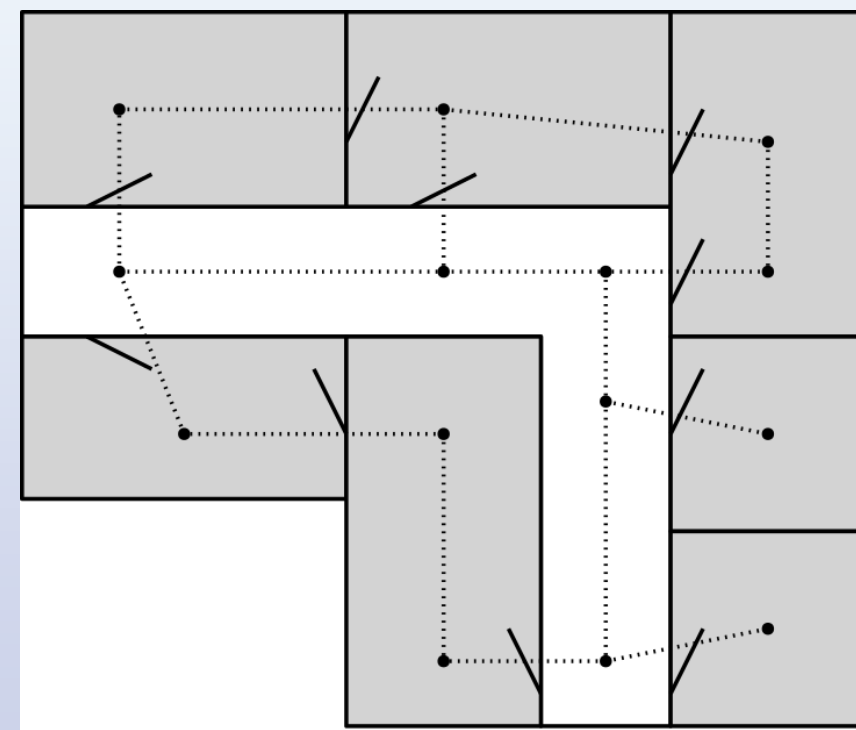
- Positioning method
- Wayfinding instructions
- A map of the environment
- A network model for calculating routes





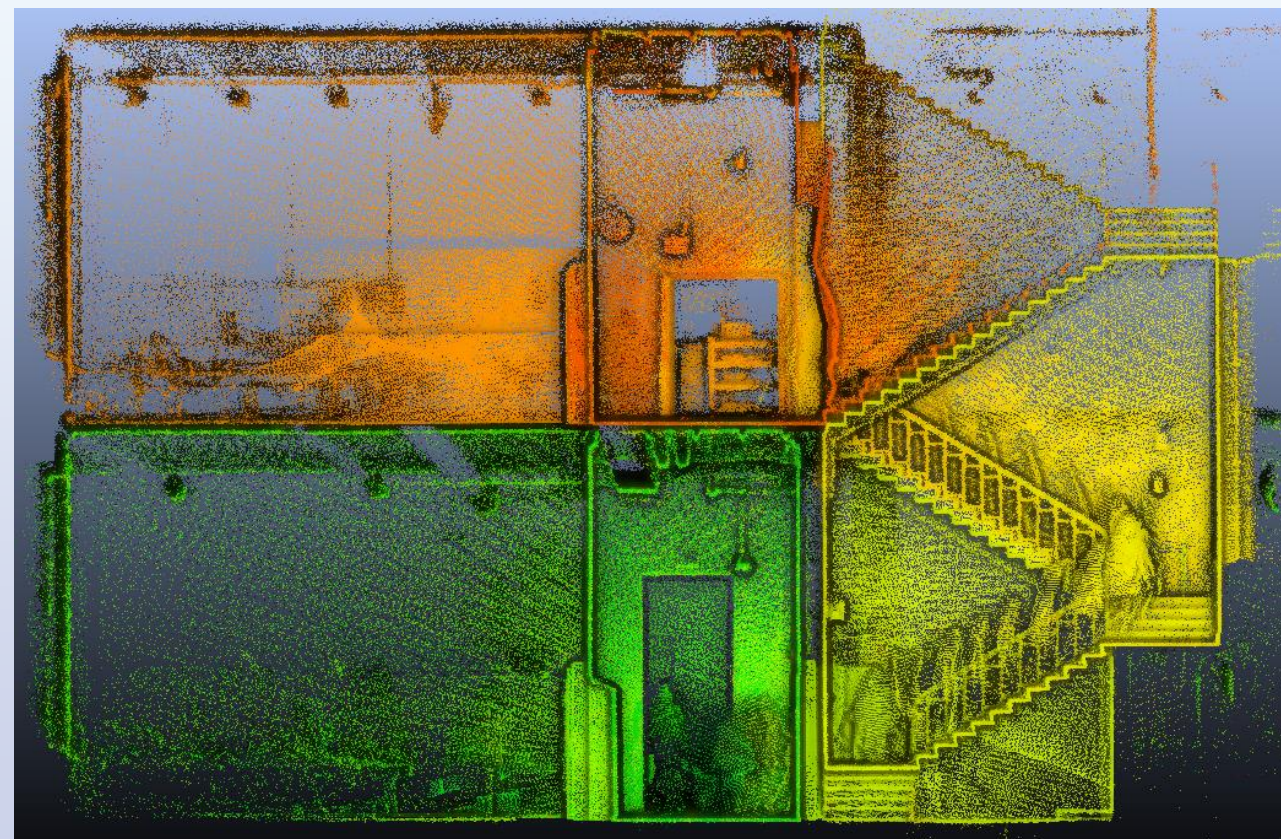
# IndoorGML

- Indoor navigation standard
- **Exchanging** indoor spatial information
  - Especially routing
- Based on **connectivity** information between indoor spaces
- **Subspacing** needed
- Can be extended with **accessibility** information



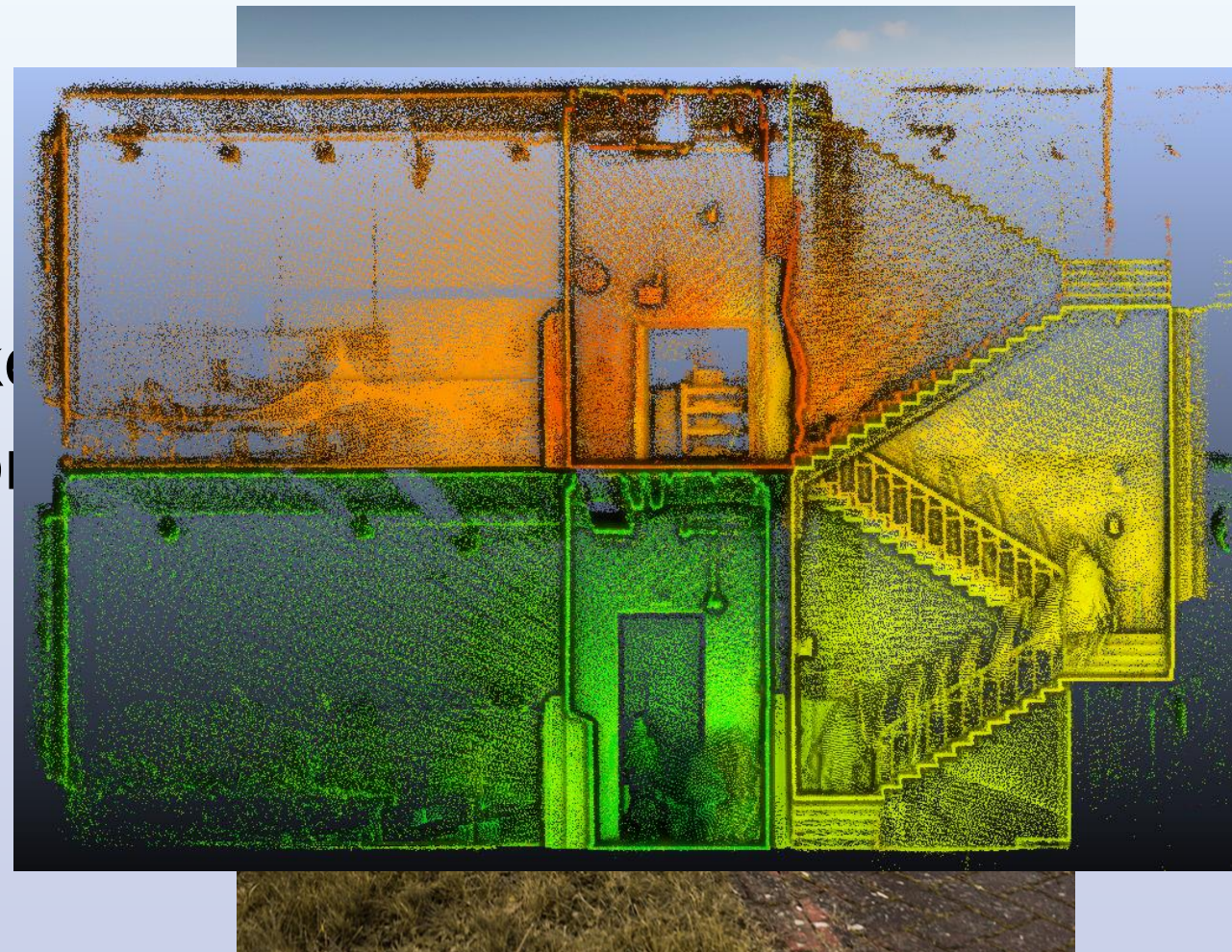
# Use of indoor point clouds

- Existing floor plans & 3D models often **outdated**
- As-built vs as-planned
- Point clouds are recent
- Furniture



# Use of indoor point clouds

- Laser scanning
- Millions of points
- Easy to obtain
- Saving the **trajectory** you walked
- Methods needed to extract information from millions of points



# Research objective

# Main objective

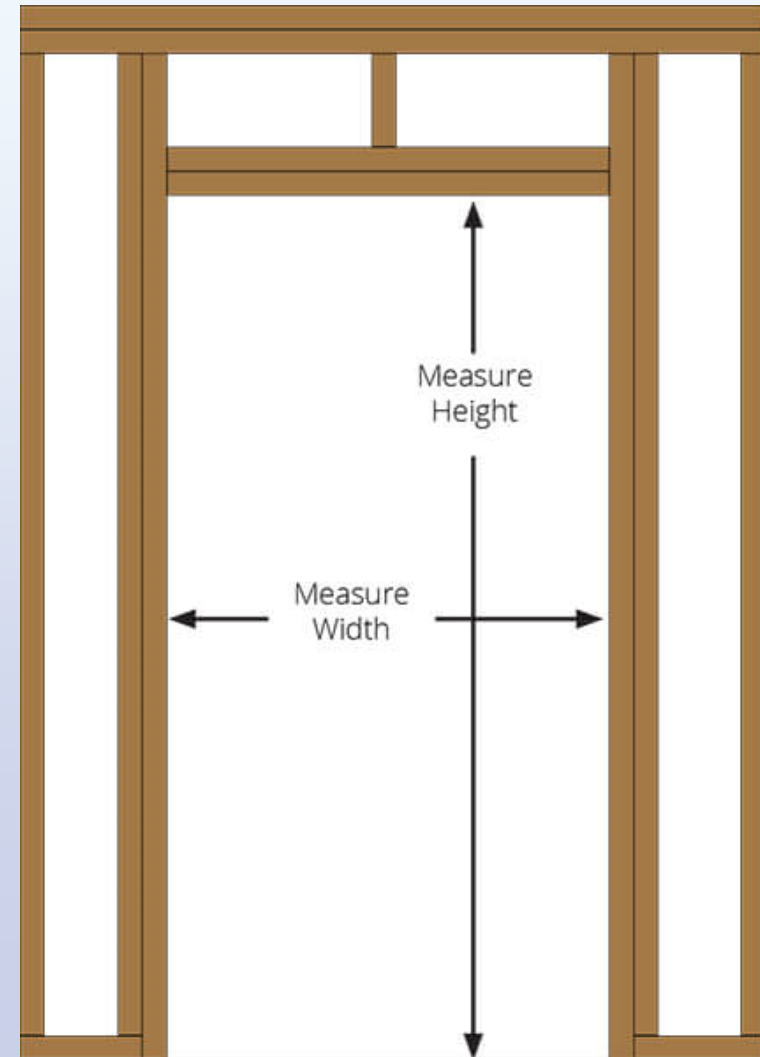
***Automatically extracting a navigation network in IndoorGML format from a cluttered indoor point cloud and its trajectory***

Cluttered: containing objects such as furniture and people



# Accessibility

- Stairs and ramps
- Height and width of doors

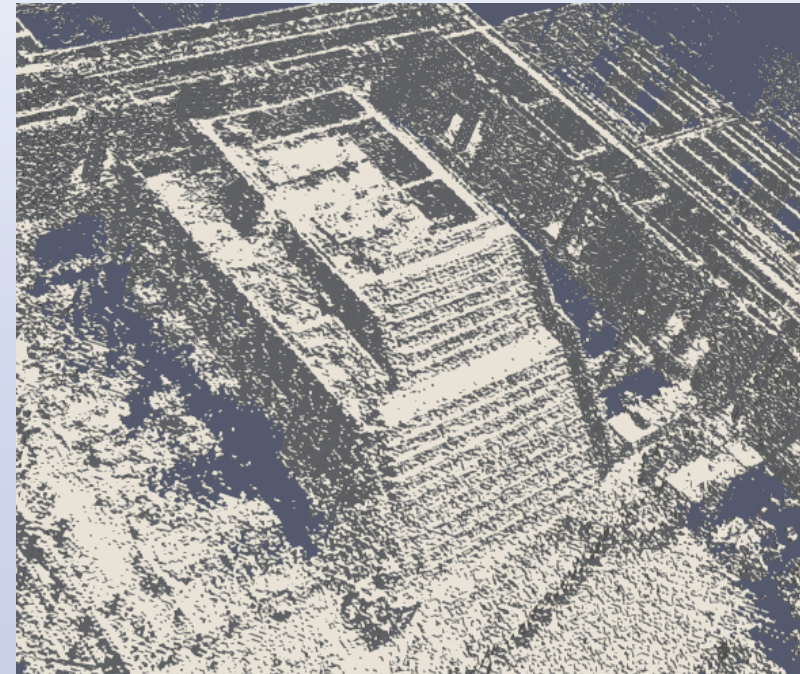
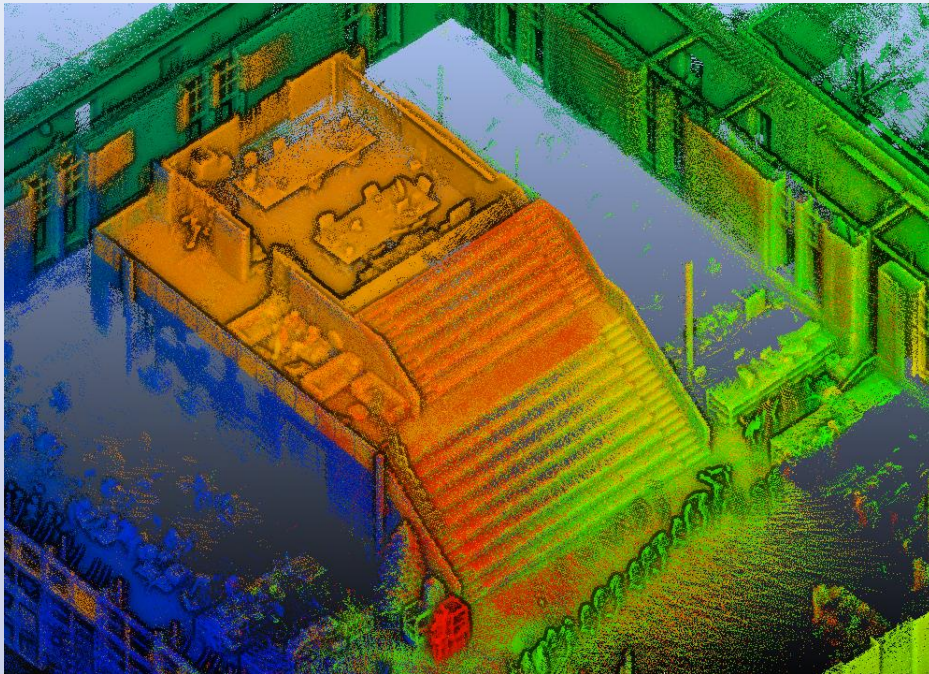


# Theory



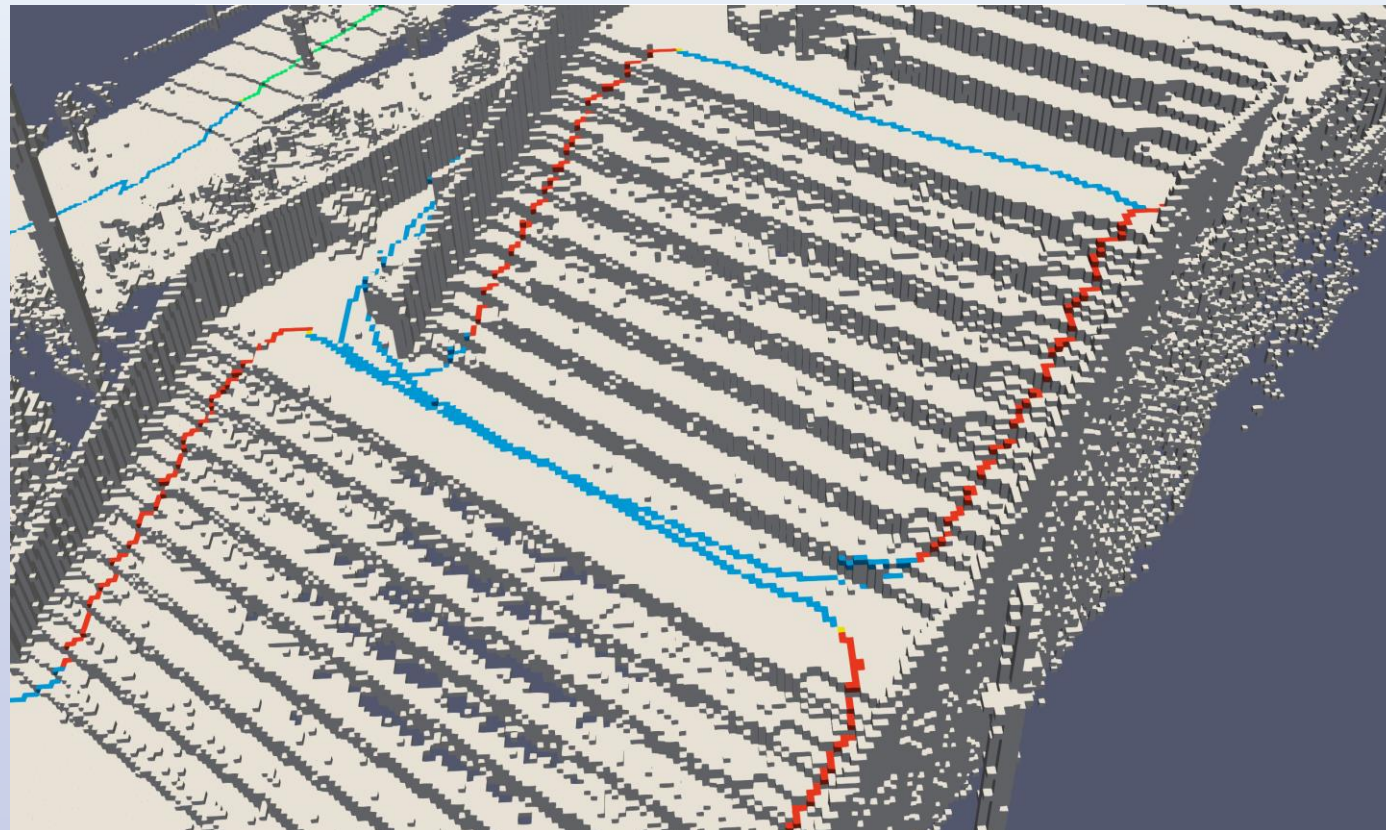
# Voxels

- Volumetric pixel
- Millions of points to thousands of voxels > faster calculations



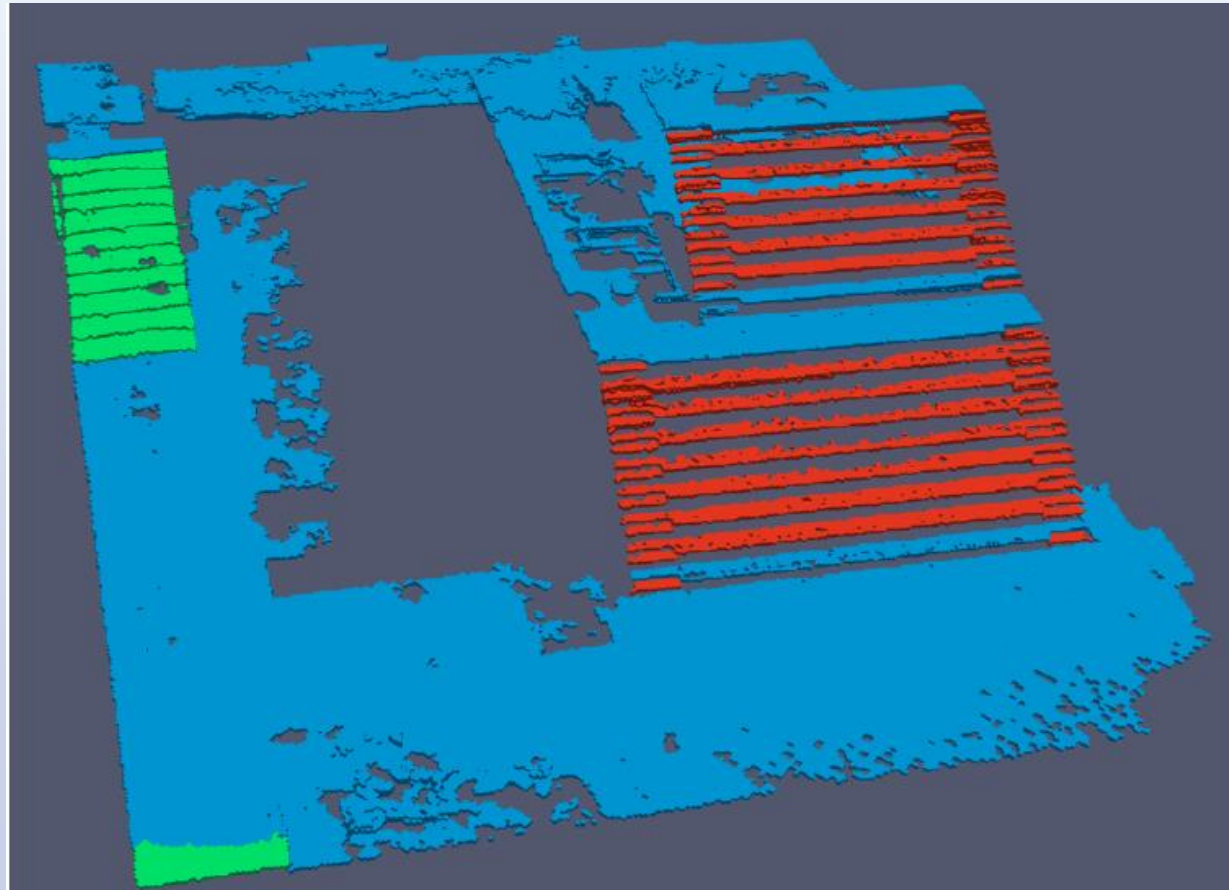
# Walkable Voxels (Staats, 2017)

- Space classified based on **angle** between trajectory and floor
- Floors (blue), Stairs (red), Ramps (green)



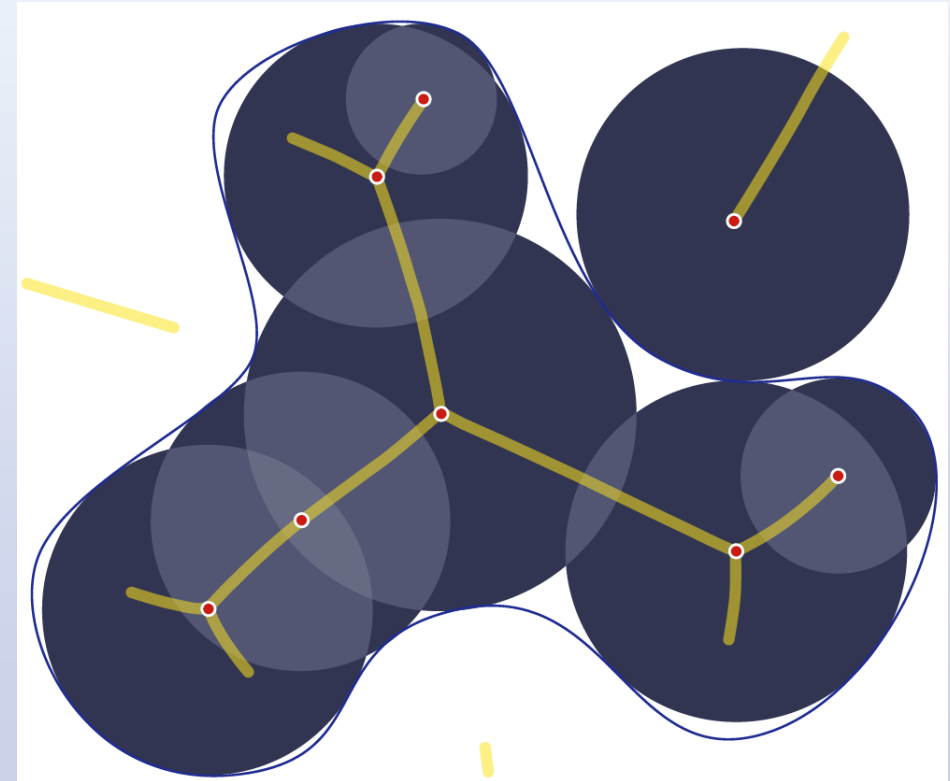
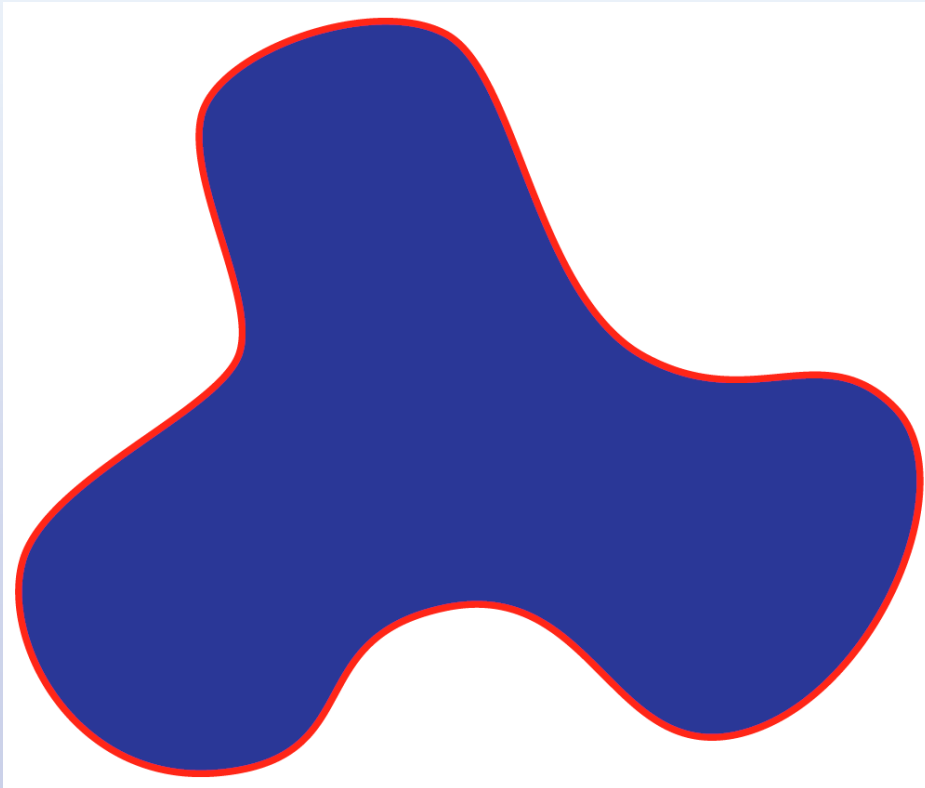
# Region growing from trajectory

- From these classified voxels: region growing



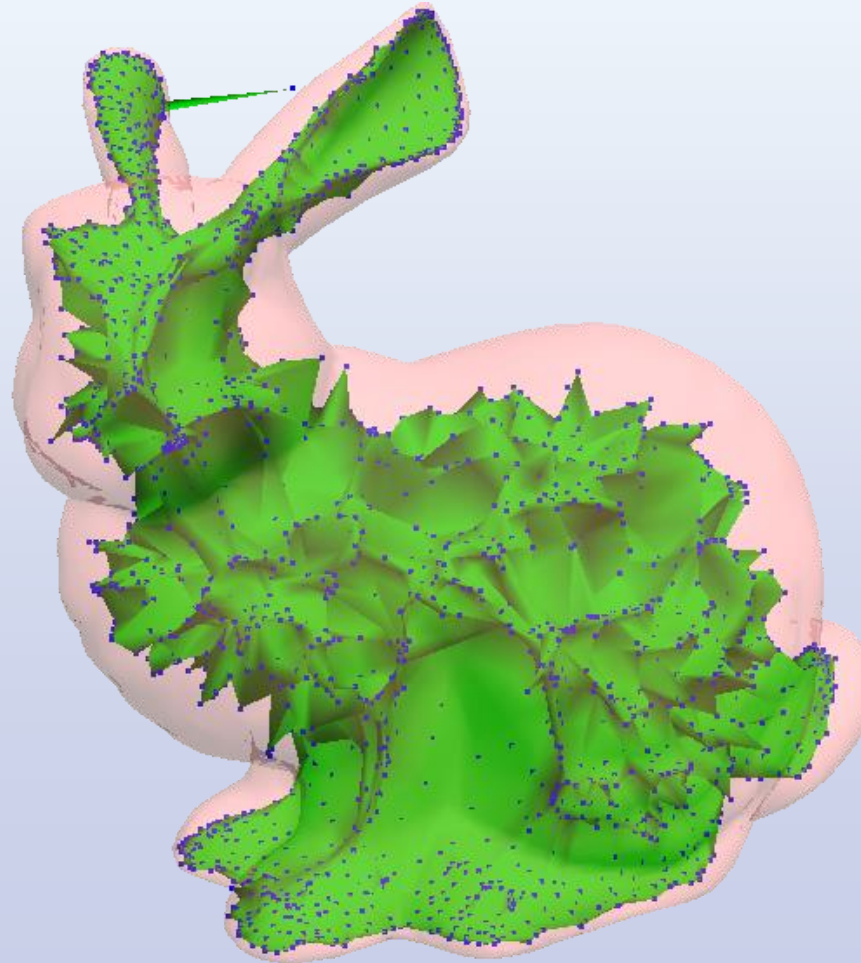
# Medial Axis Transform (MAT)

- The “skeleton” of a shape



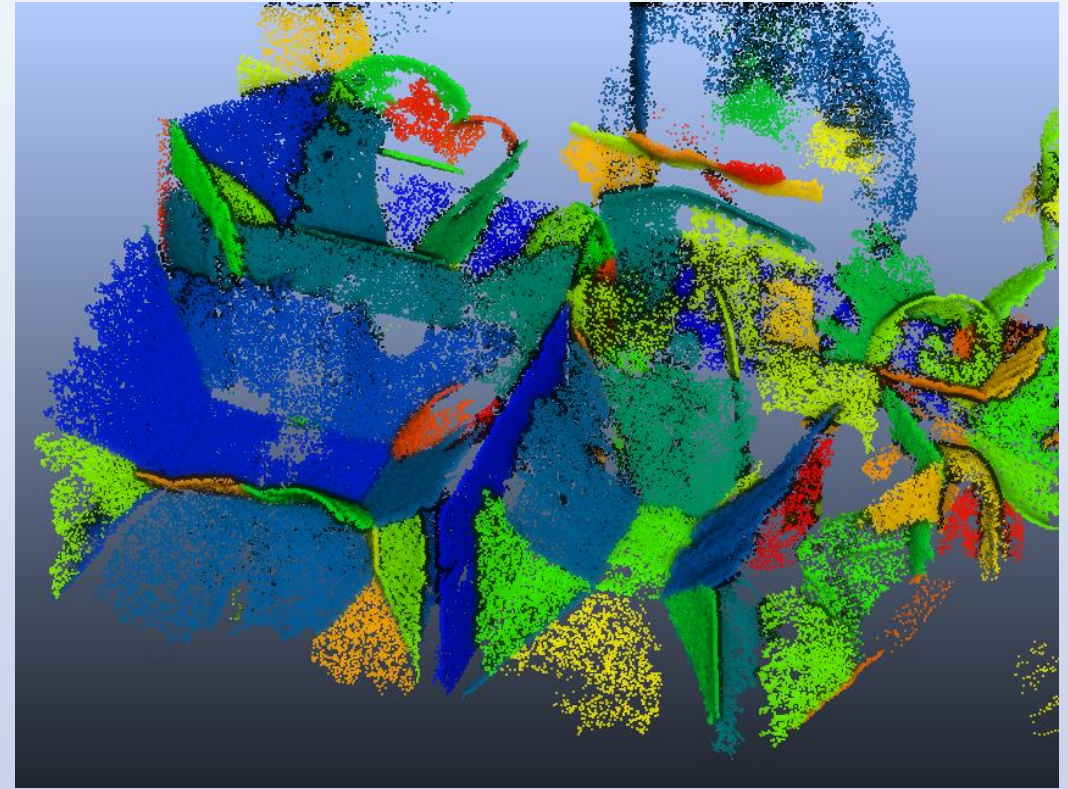
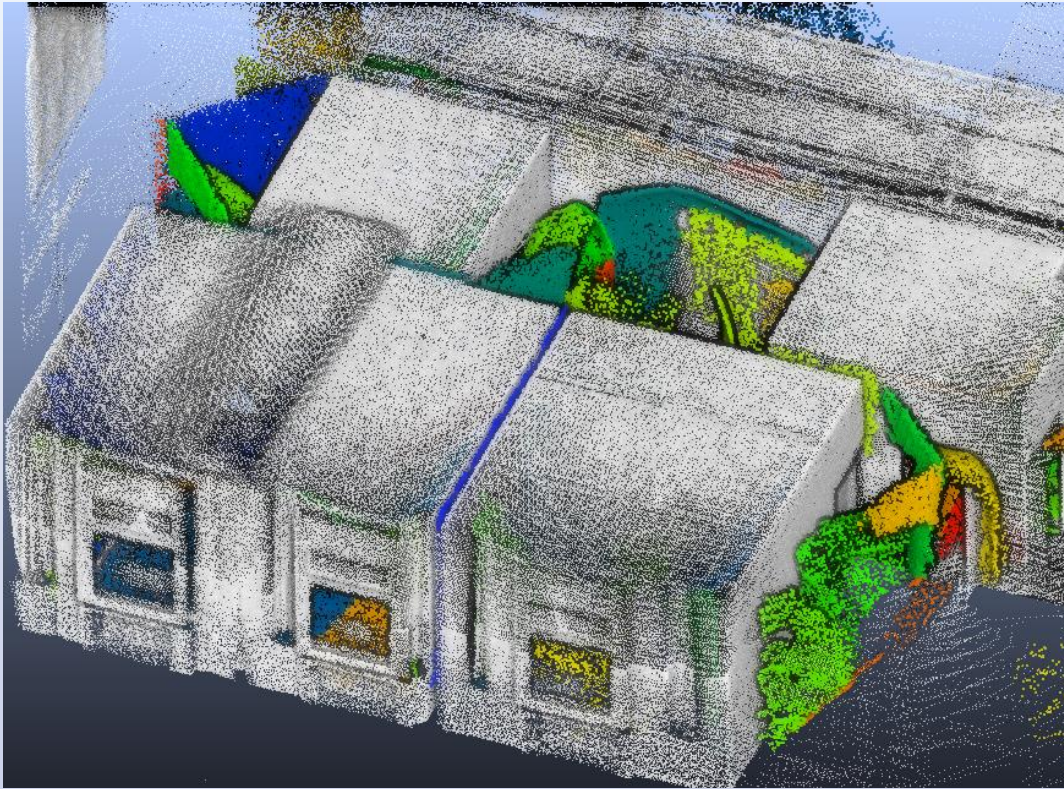
# 3D MAT of a shape

- Surfaces instead of lines



# 3D MAT on point clouds (Peters, 2018)

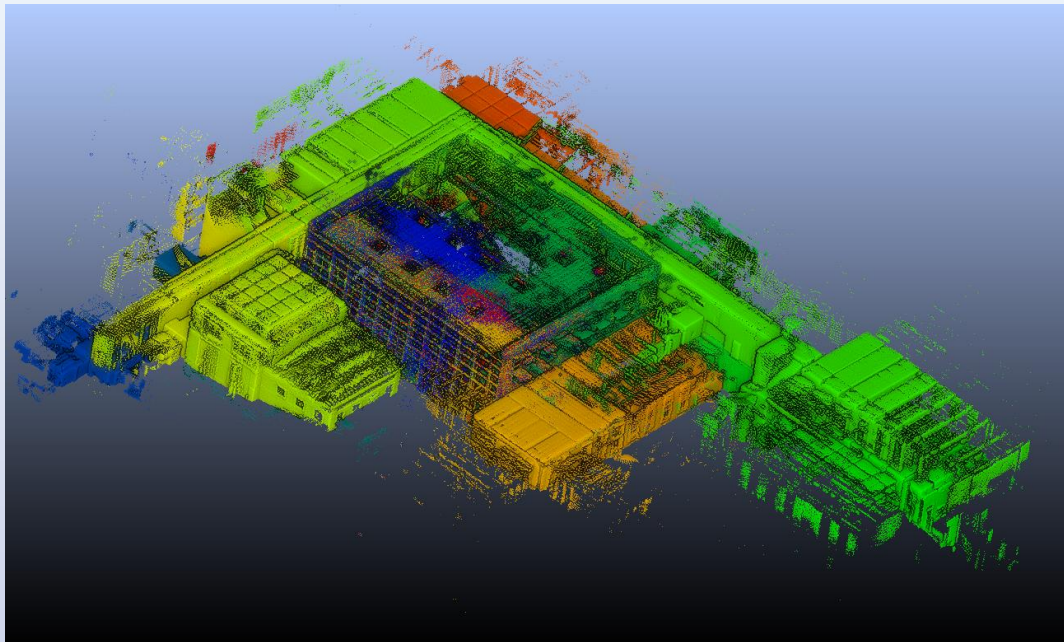
- Sheets of points representing surfaces



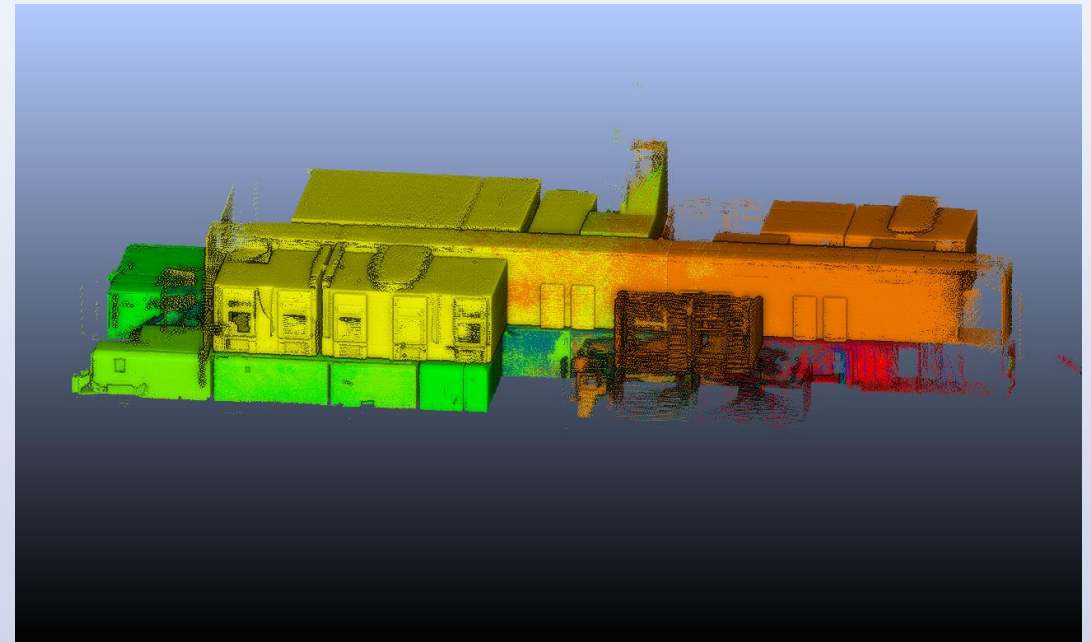
# Methodology

# Point clouds used

Development point cloud (TU Delft)



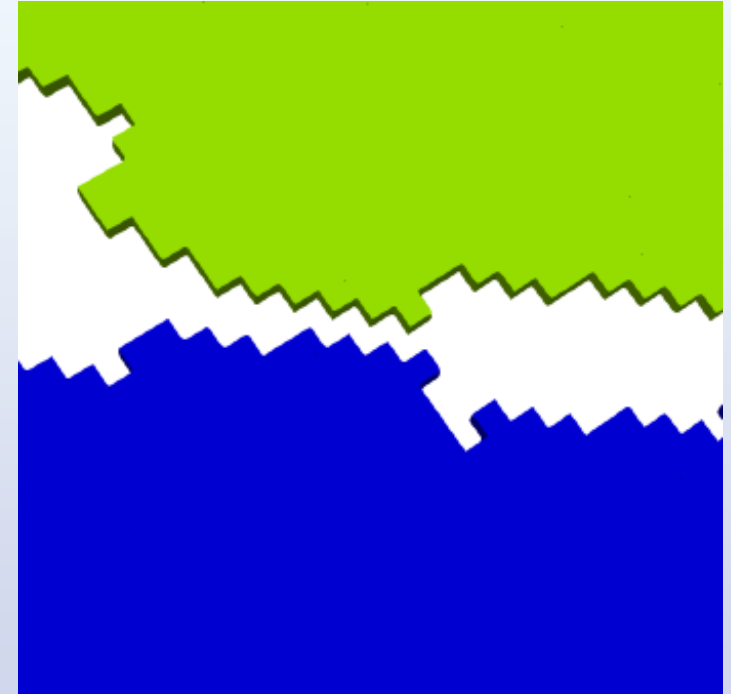
Test point cloud (TUBerlin)





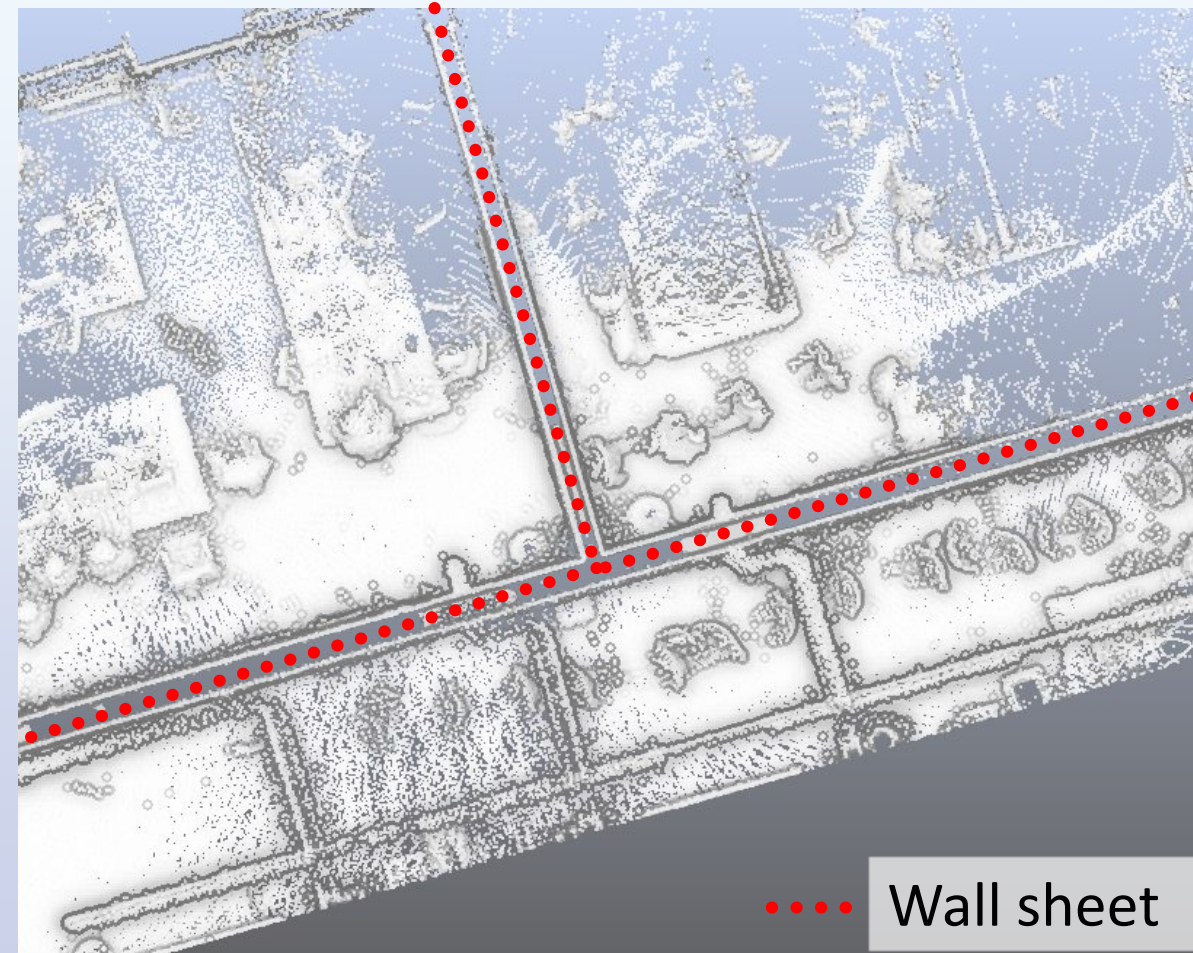
# Door detection

- Besides location of door:
- Create a **gap** between floor of rooms, so inside the door frame
- The two rooms will be grown into separate regions



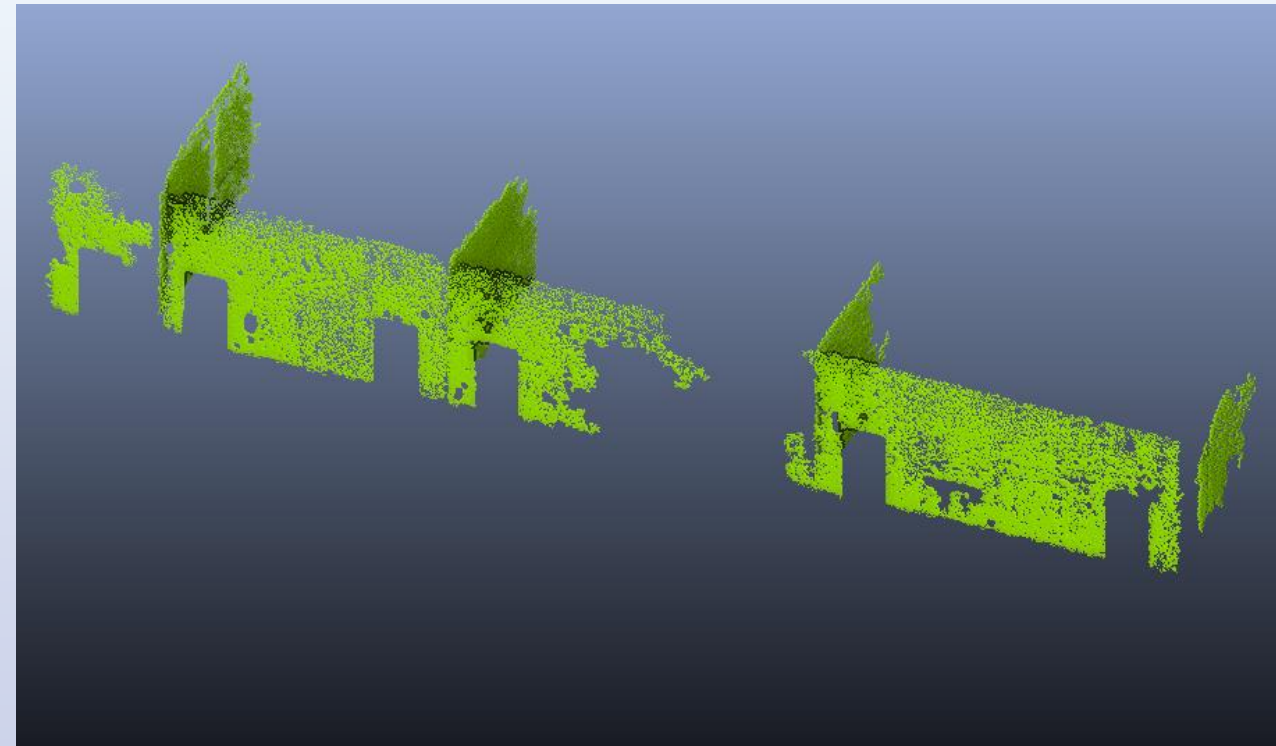
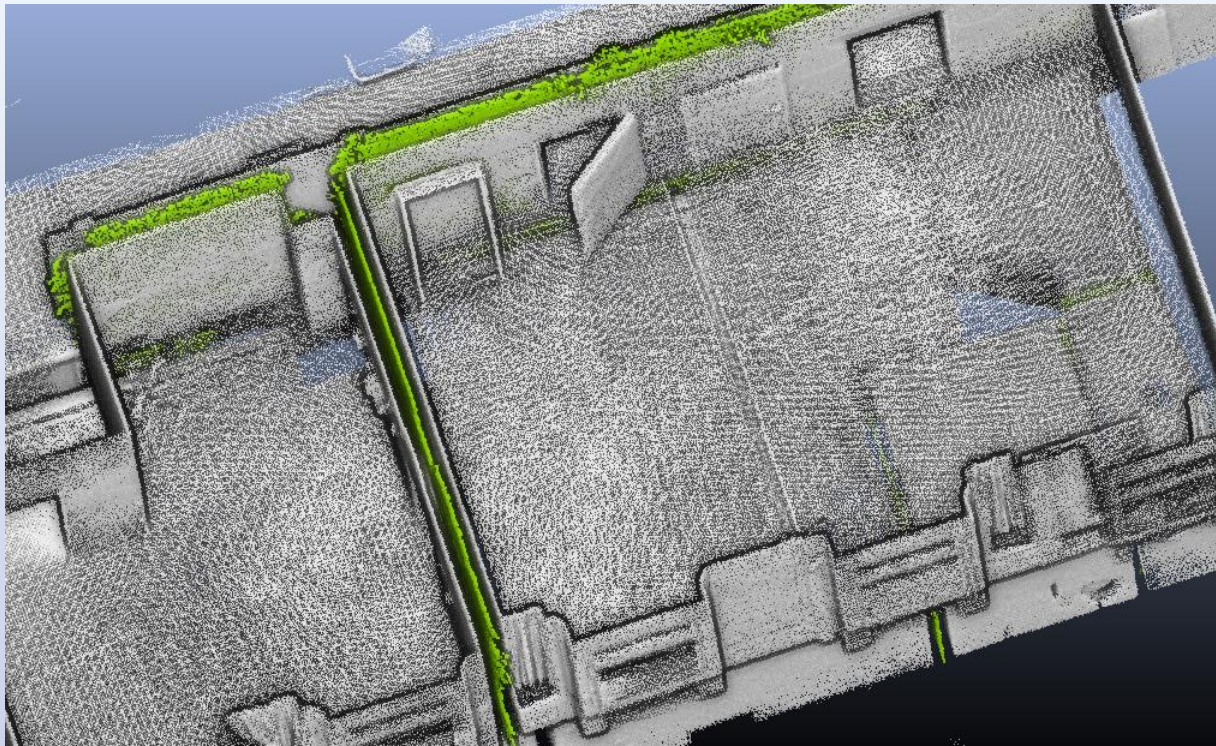
# 3D Medial Axis Transform (MAT) (Peters, 2018)

- 3D MAT applied on indoor point cloud
- Medial sheets also formed inside walls
- These are classified by applying filtering parameters



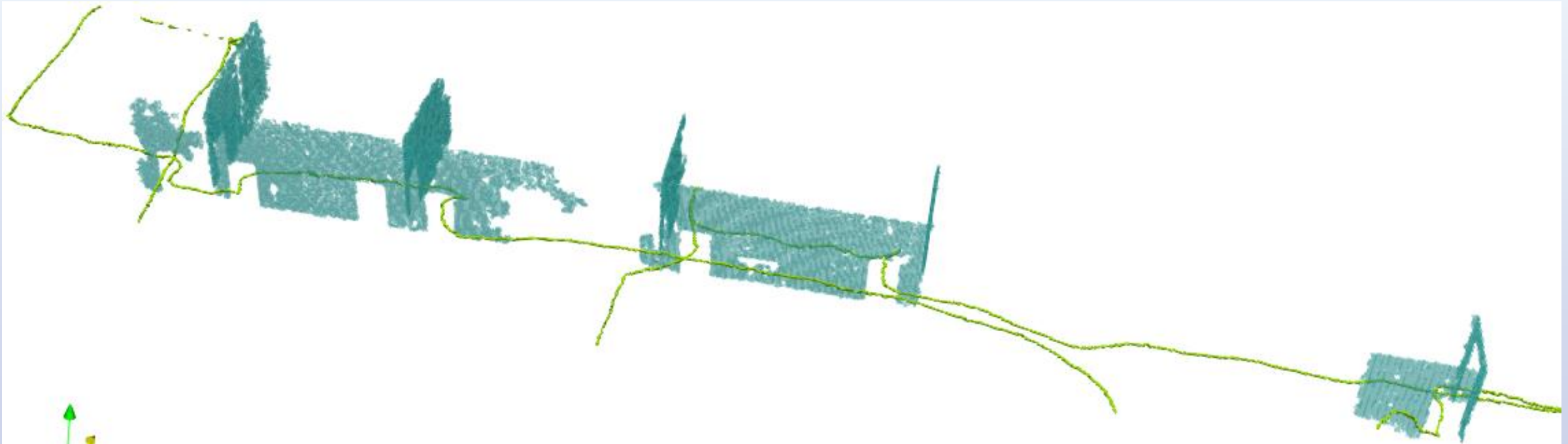
Top view of point cloud

# Medial wall sheets



# Door detection using 3D MAT sheet voxels

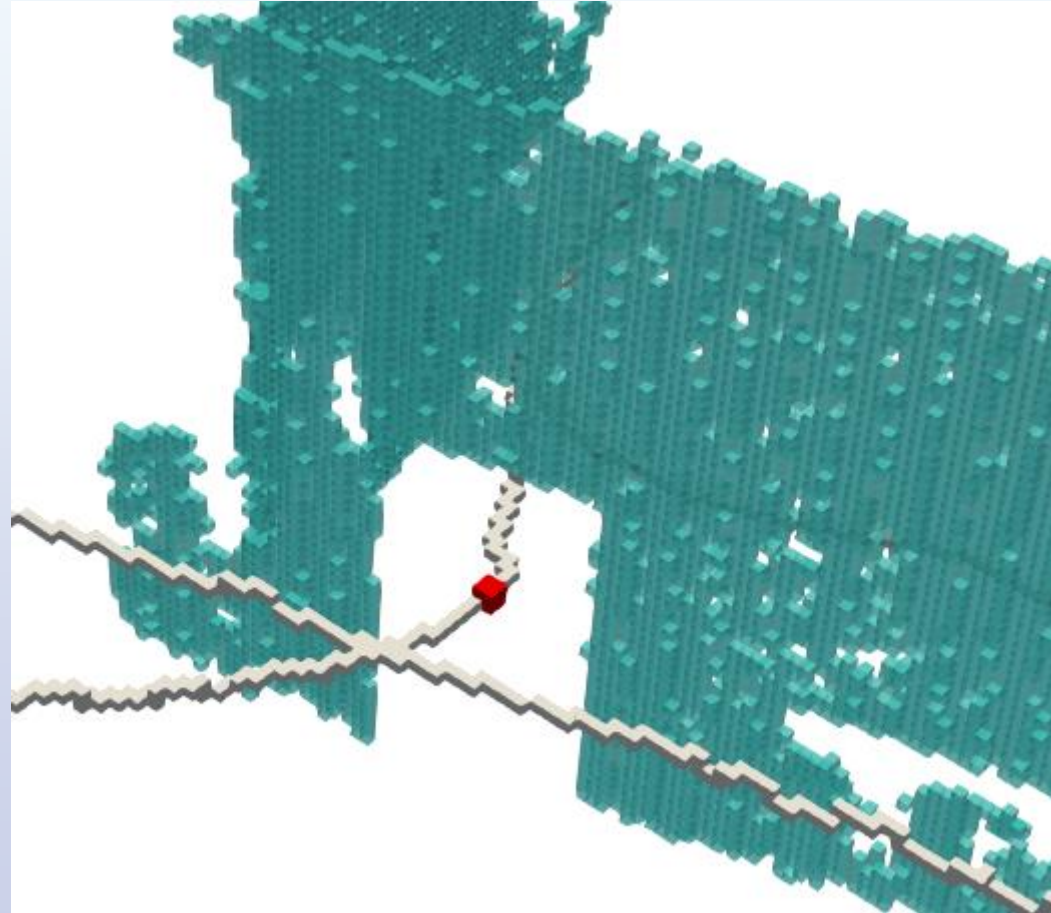
- Together with trajectory



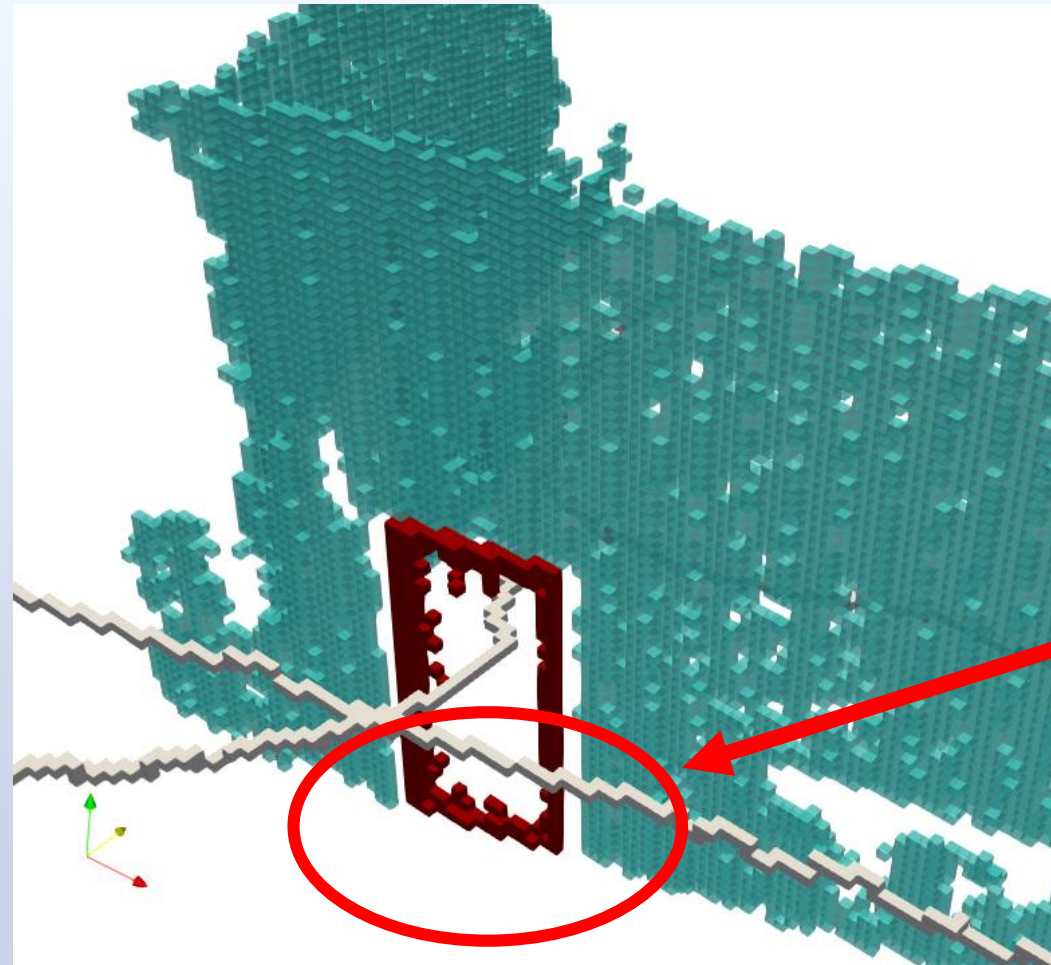
# Door detection using 3D MAT sheet voxels

- There is a door when there are MAT sheet voxels **above** the trajectory
- There is a door when there are MAT sheet voxels **on both sides** of the trajectory

# MAT voxels above trajectory



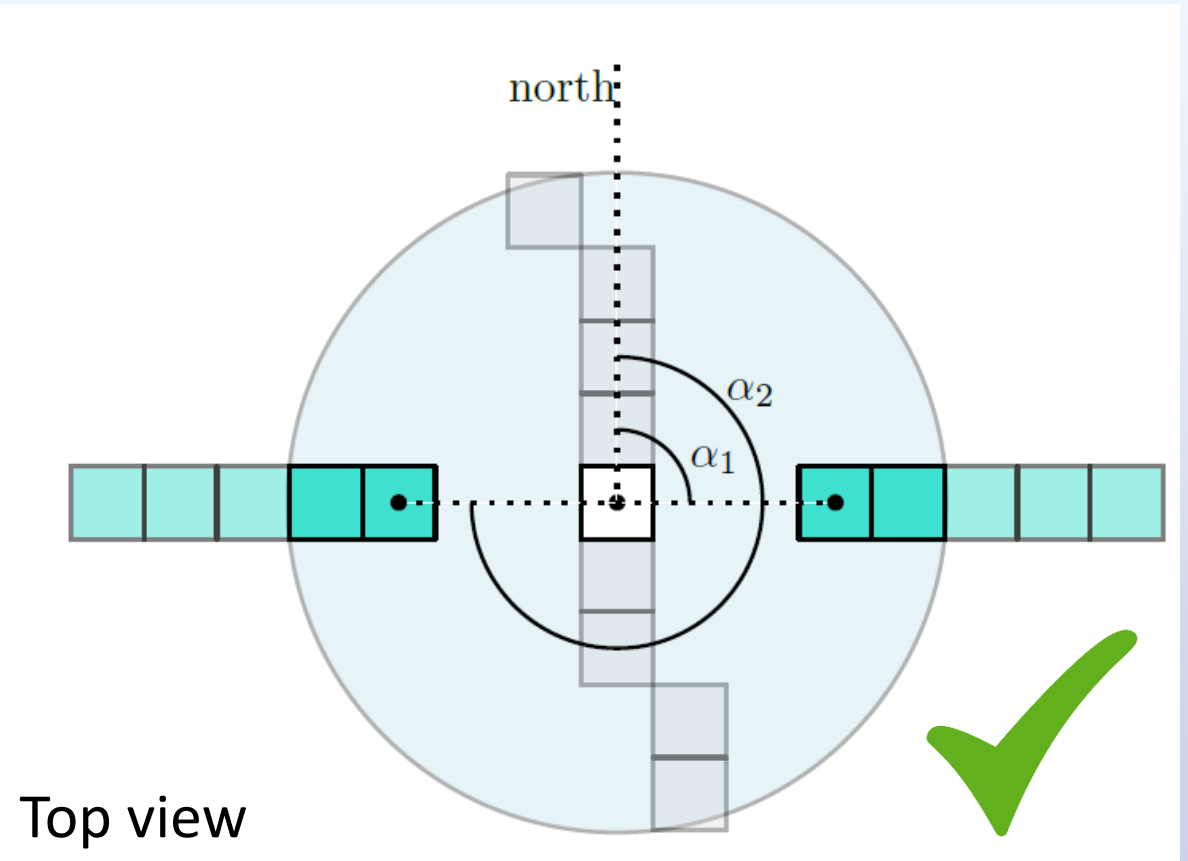
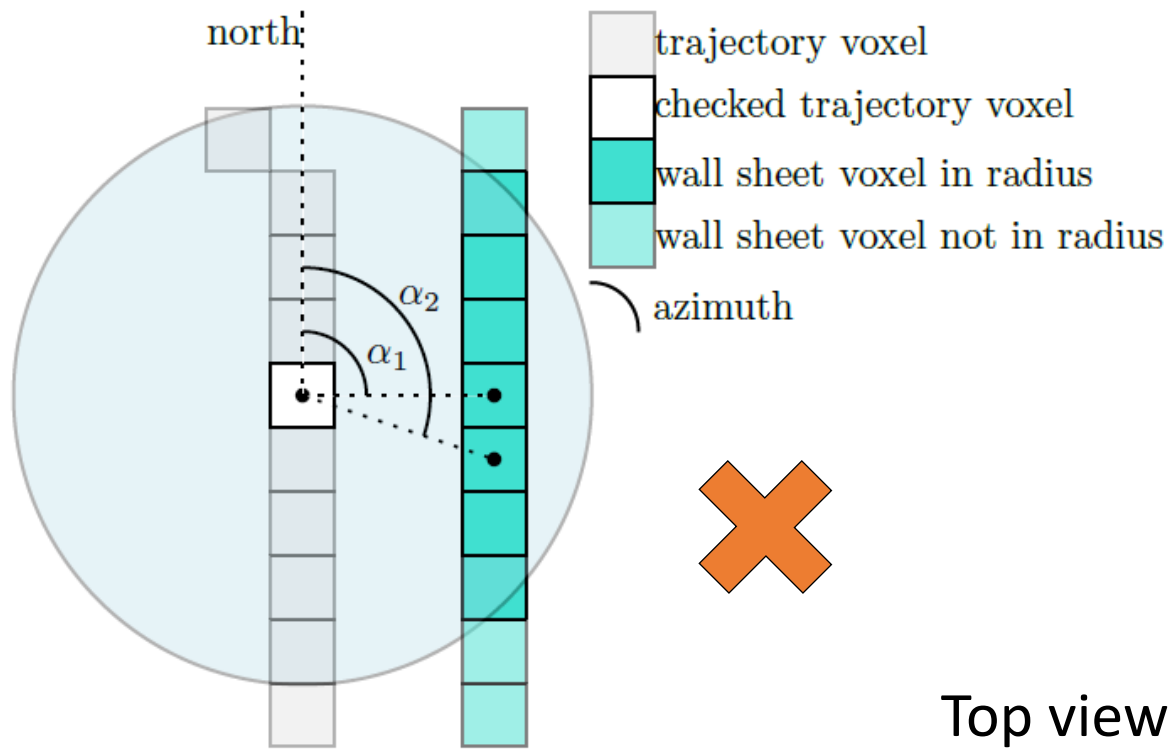
# MAT voxels above original point cloud



Voxels on the floor to create a gap

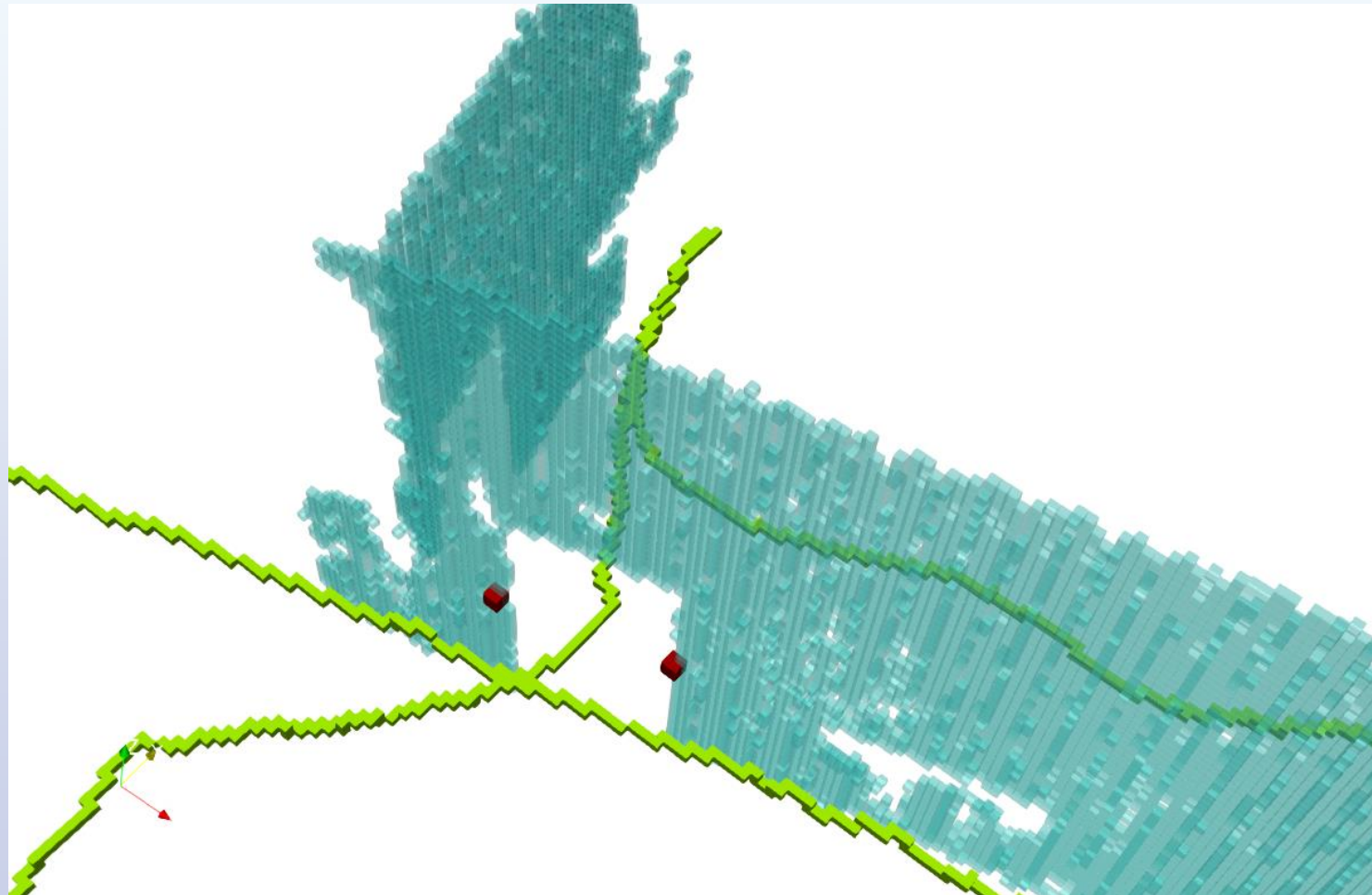
# Voxels on both sides of trajectory

Find where  $|\alpha_1 - \alpha_2| \cong 180^\circ$

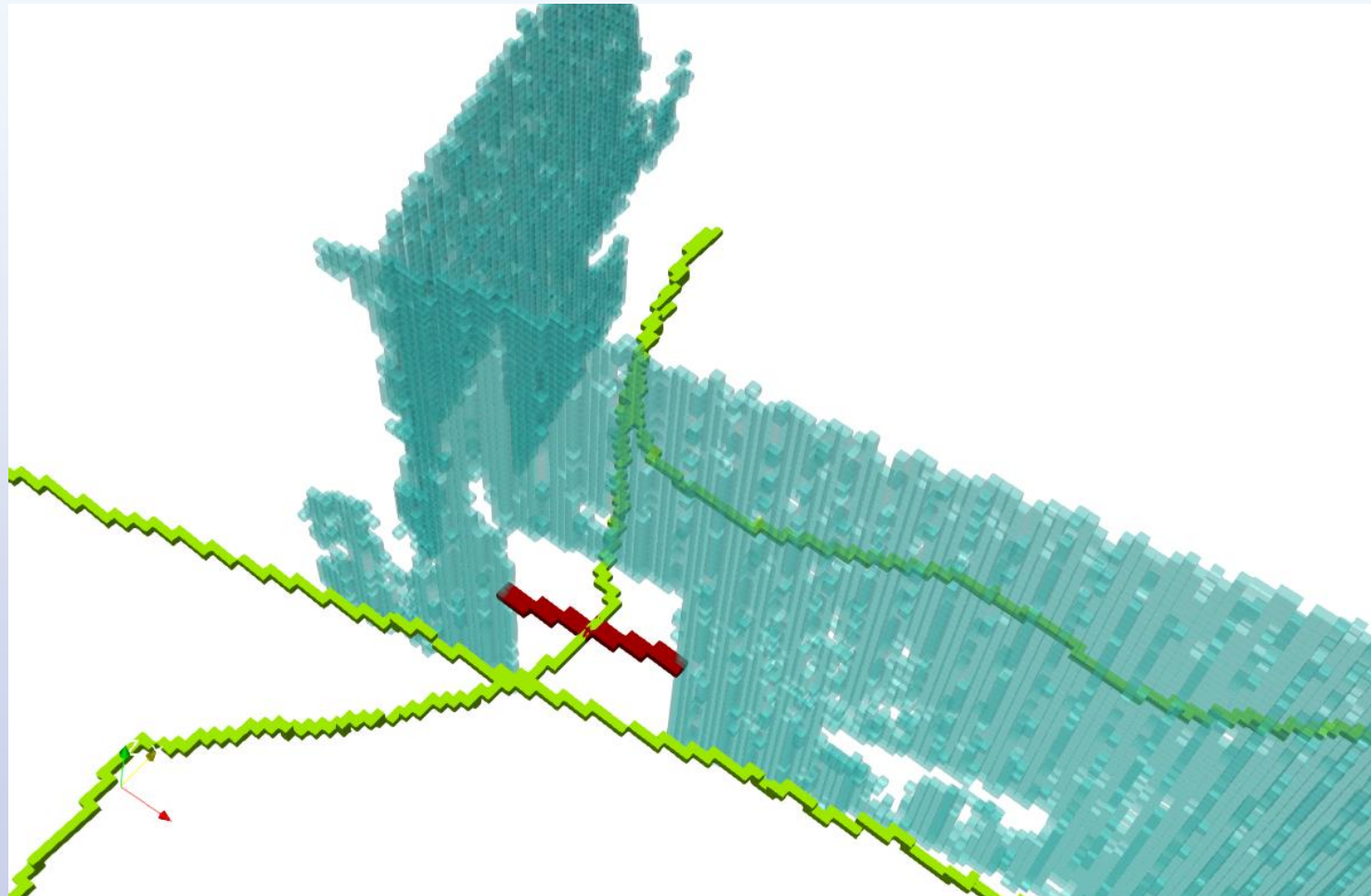




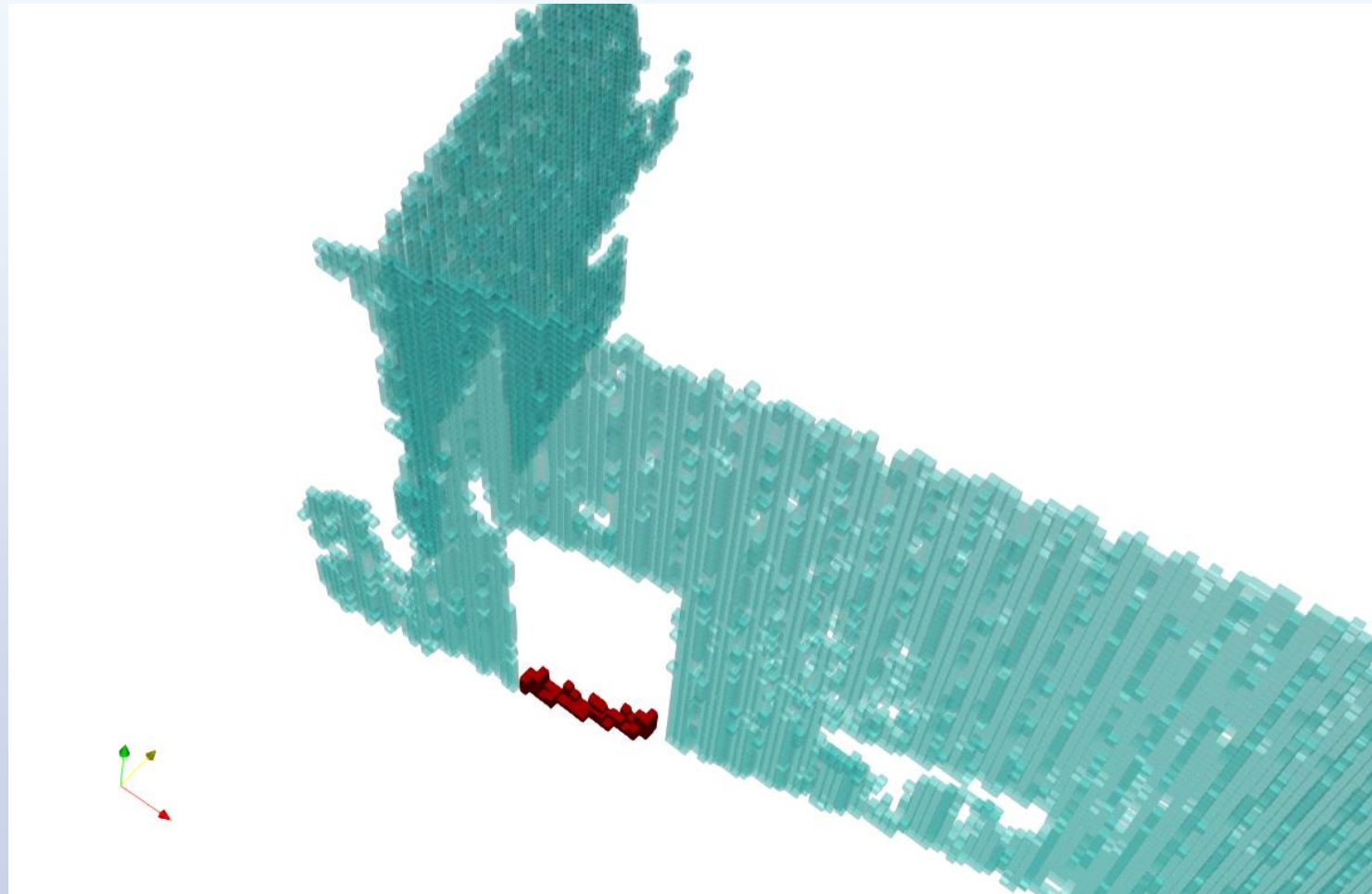
# MAT voxels on both sides of trajectory



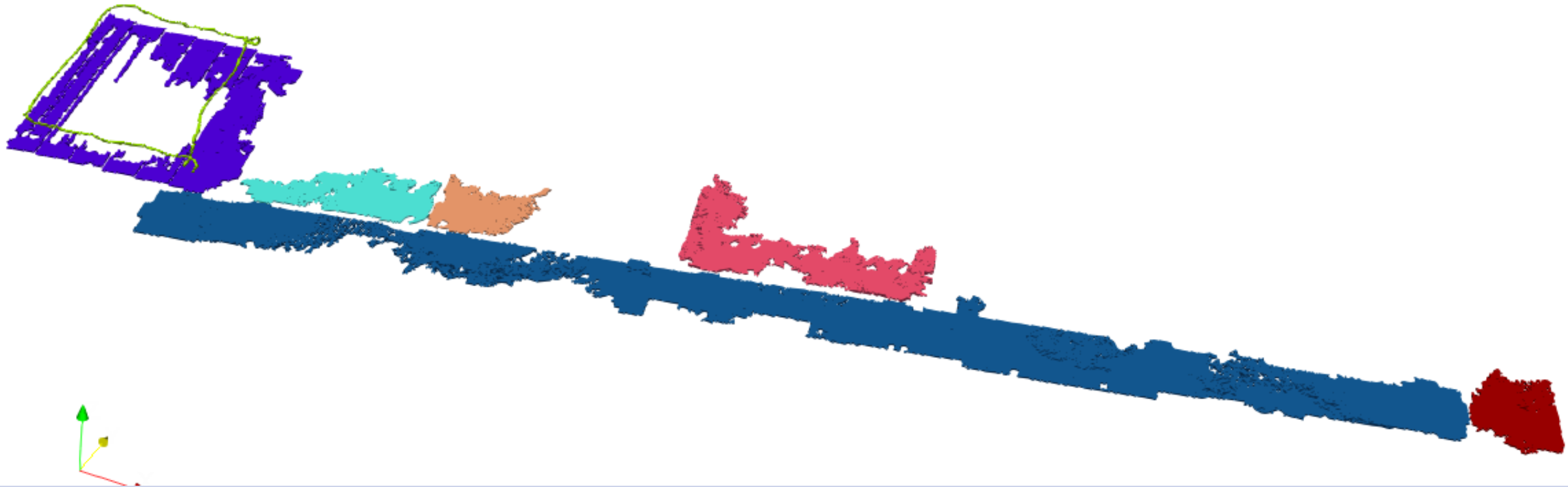
# Draw line between the pair of voxels



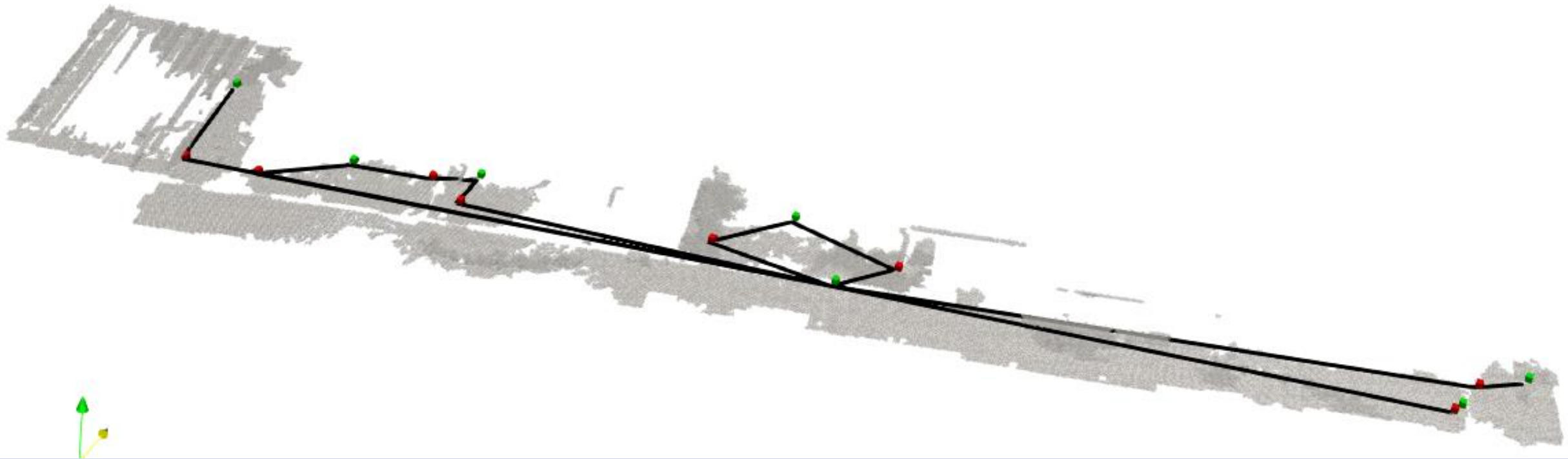
# Find voxels below line on the floor in the door



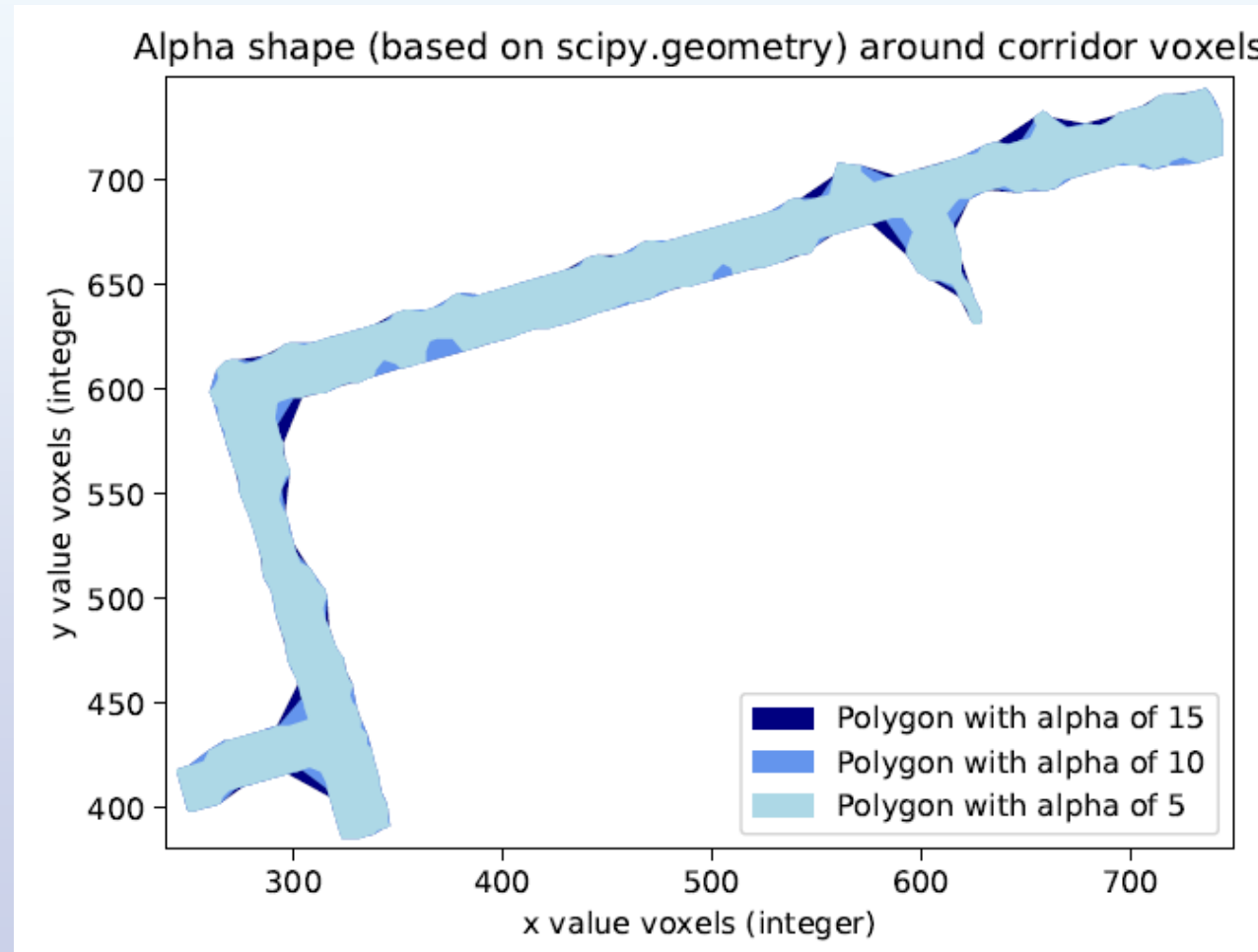
# Creating separate indoor spaces



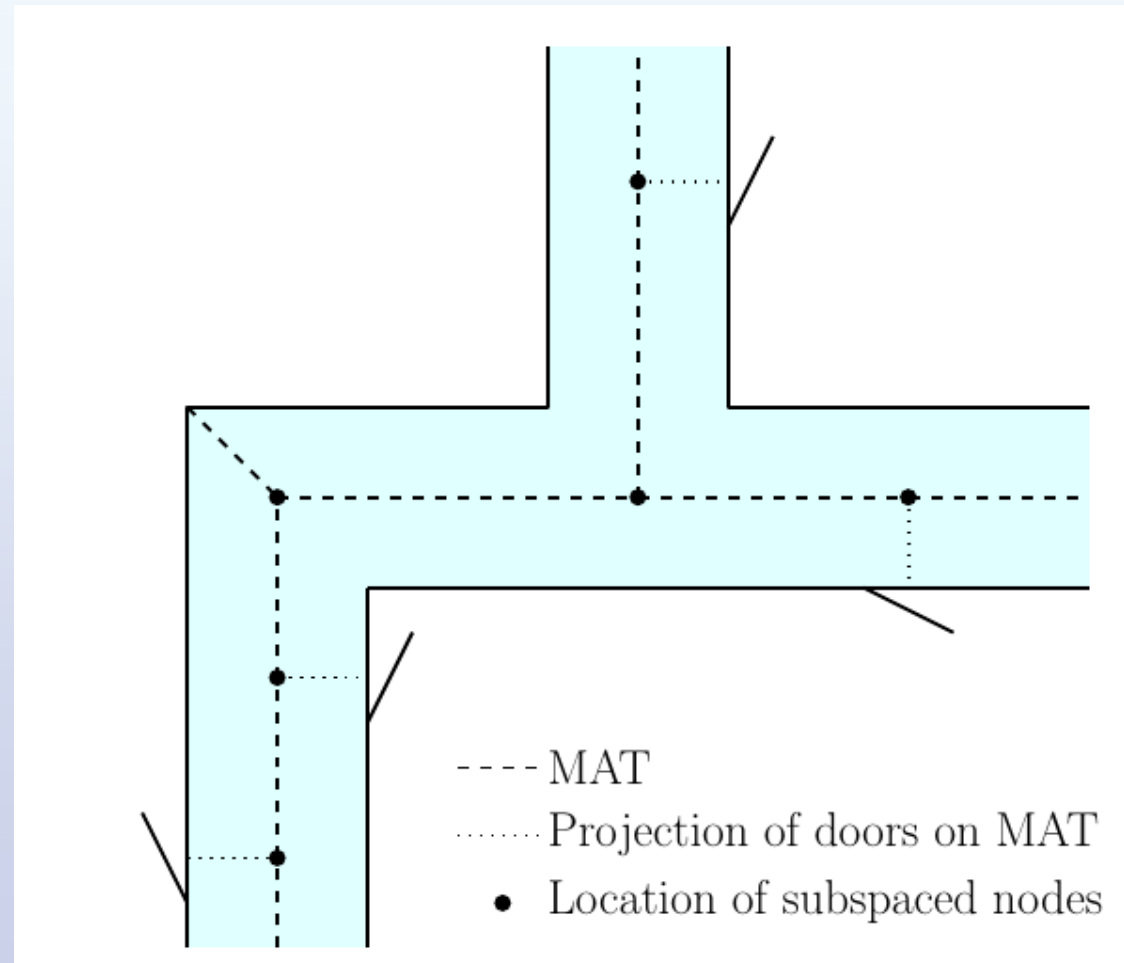
# Connectivity graph



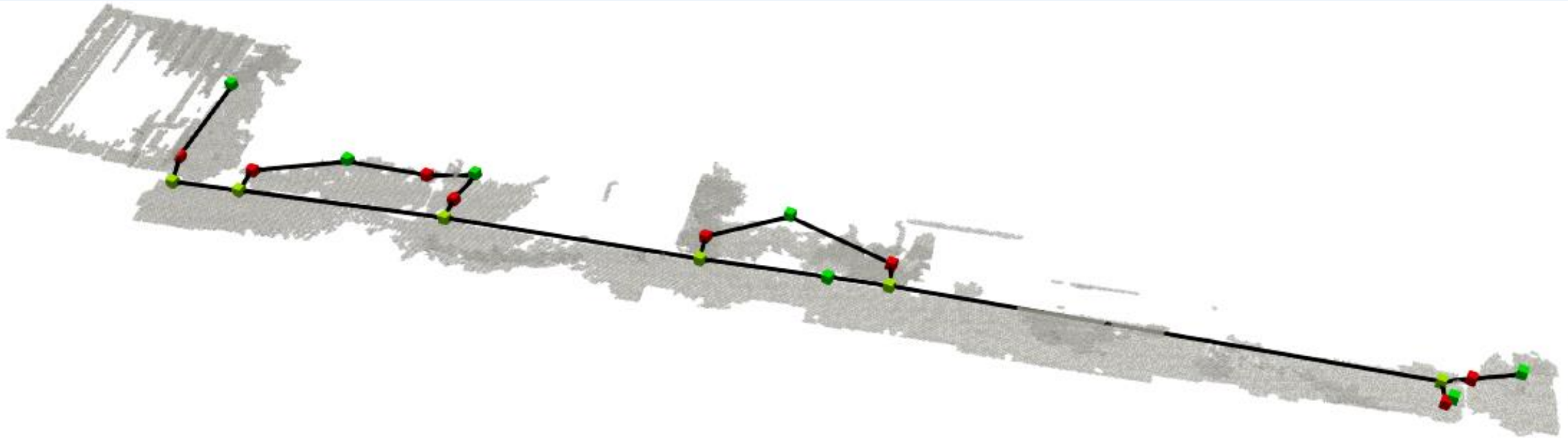
# Alpha shape modelling



# Subspacing corridor with MAT

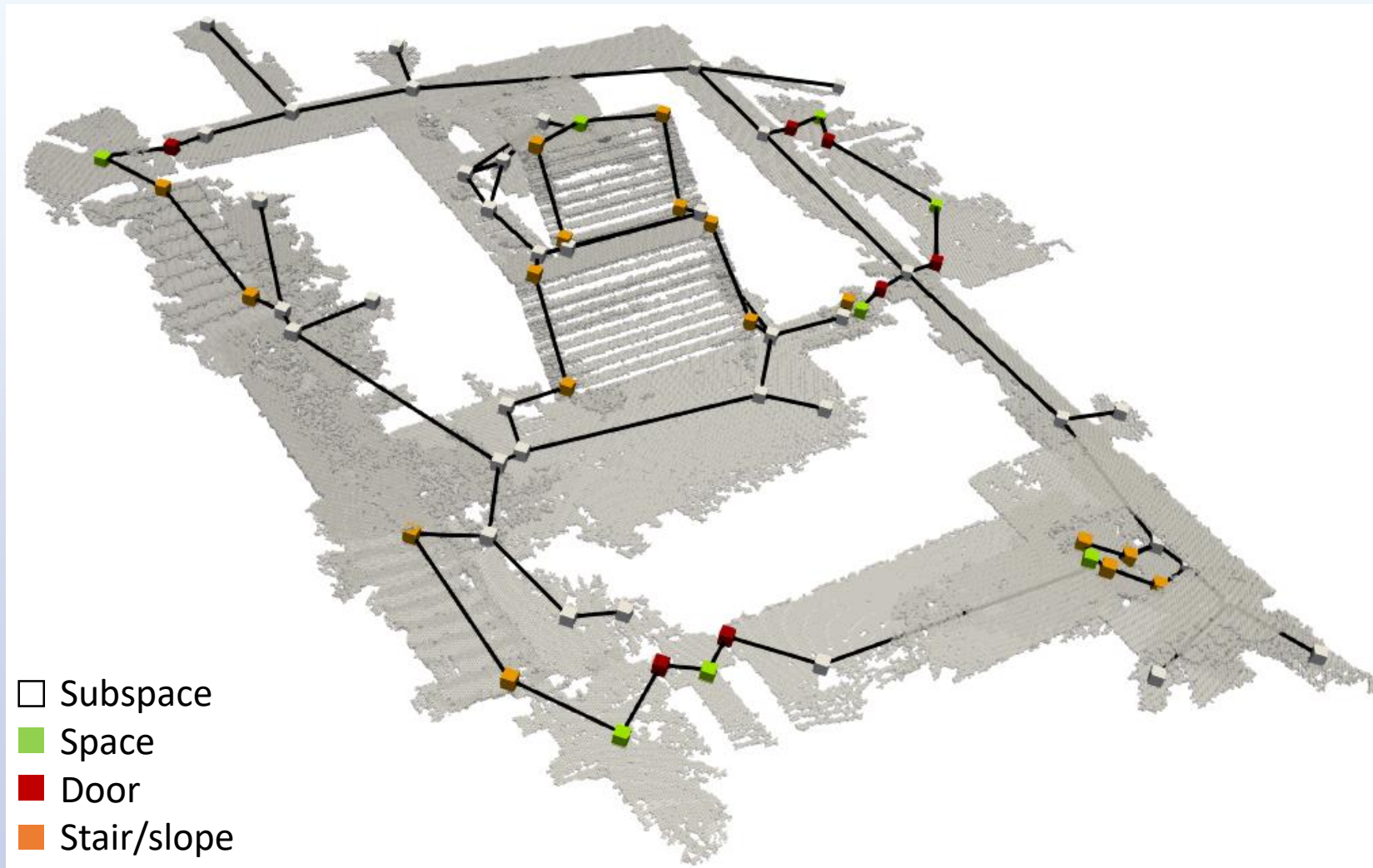


# Result of subsampling

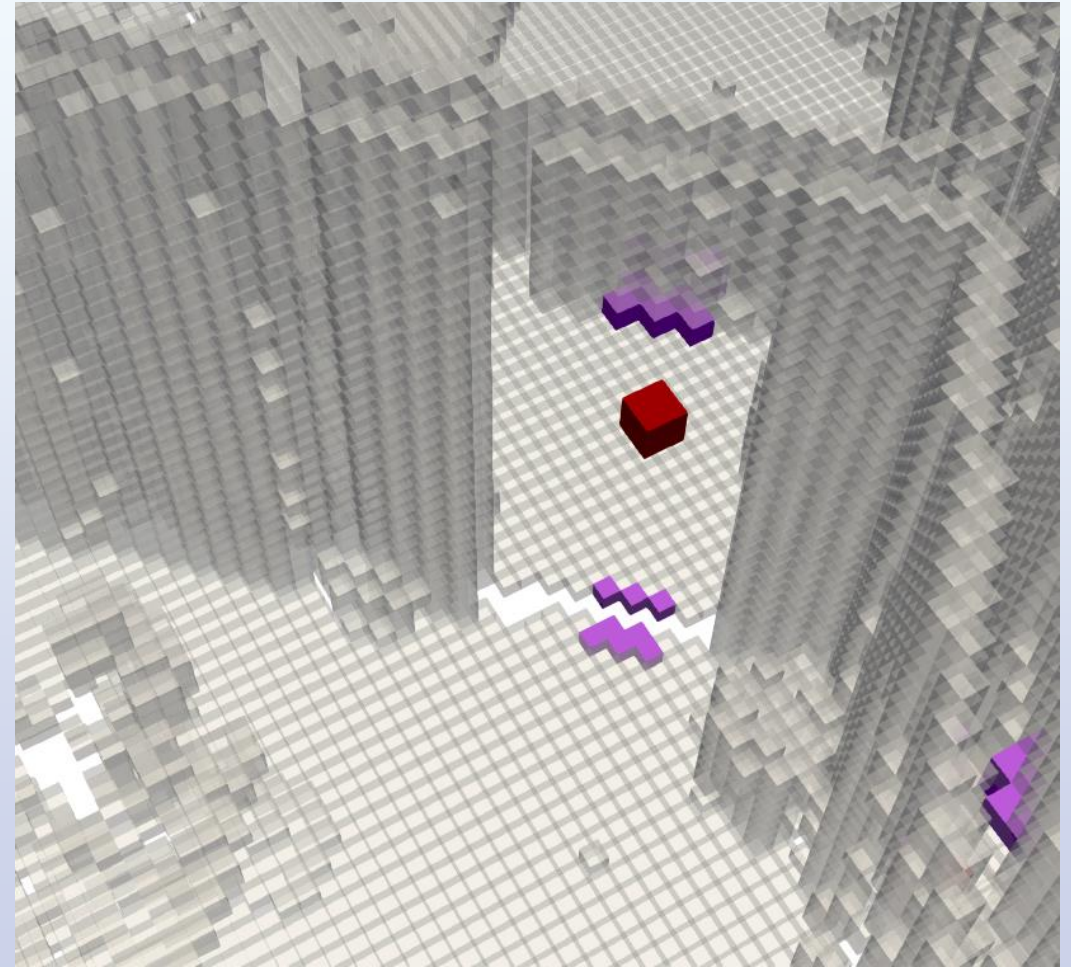
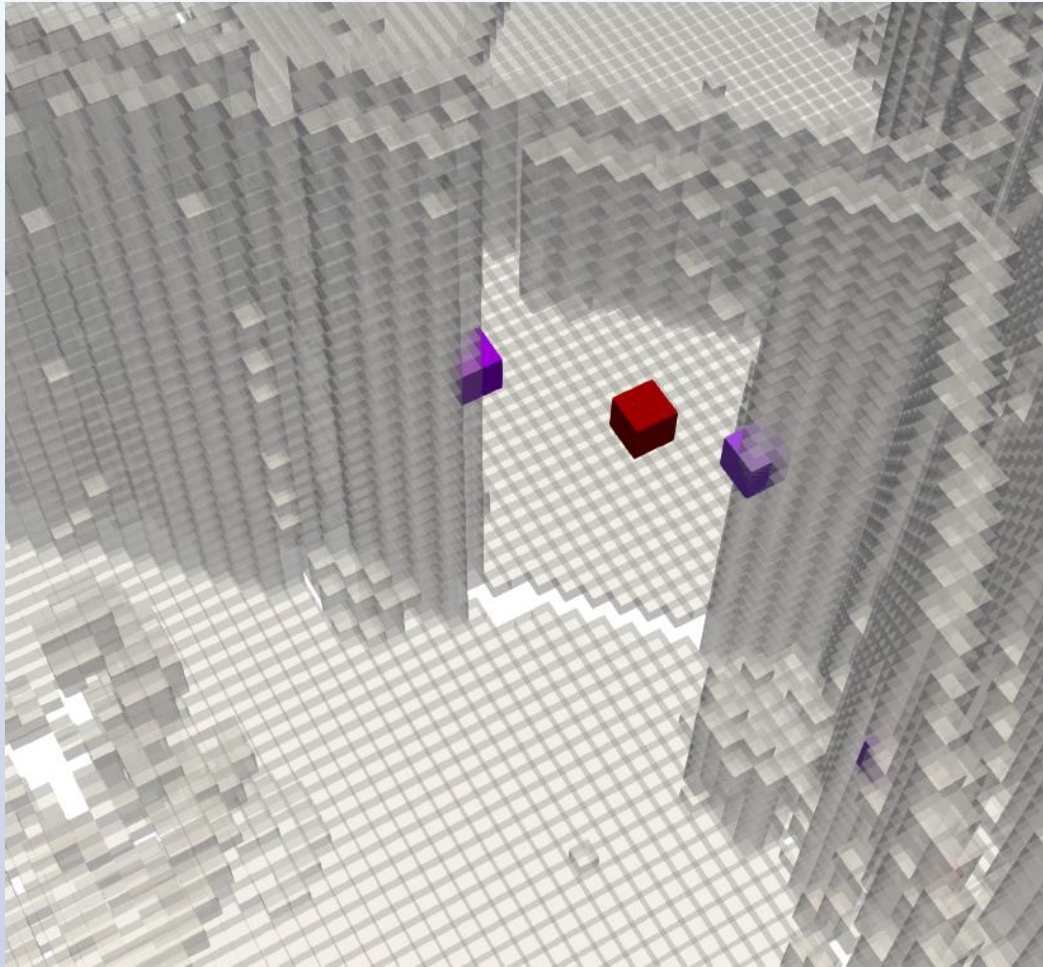




# Accessibility: stairs

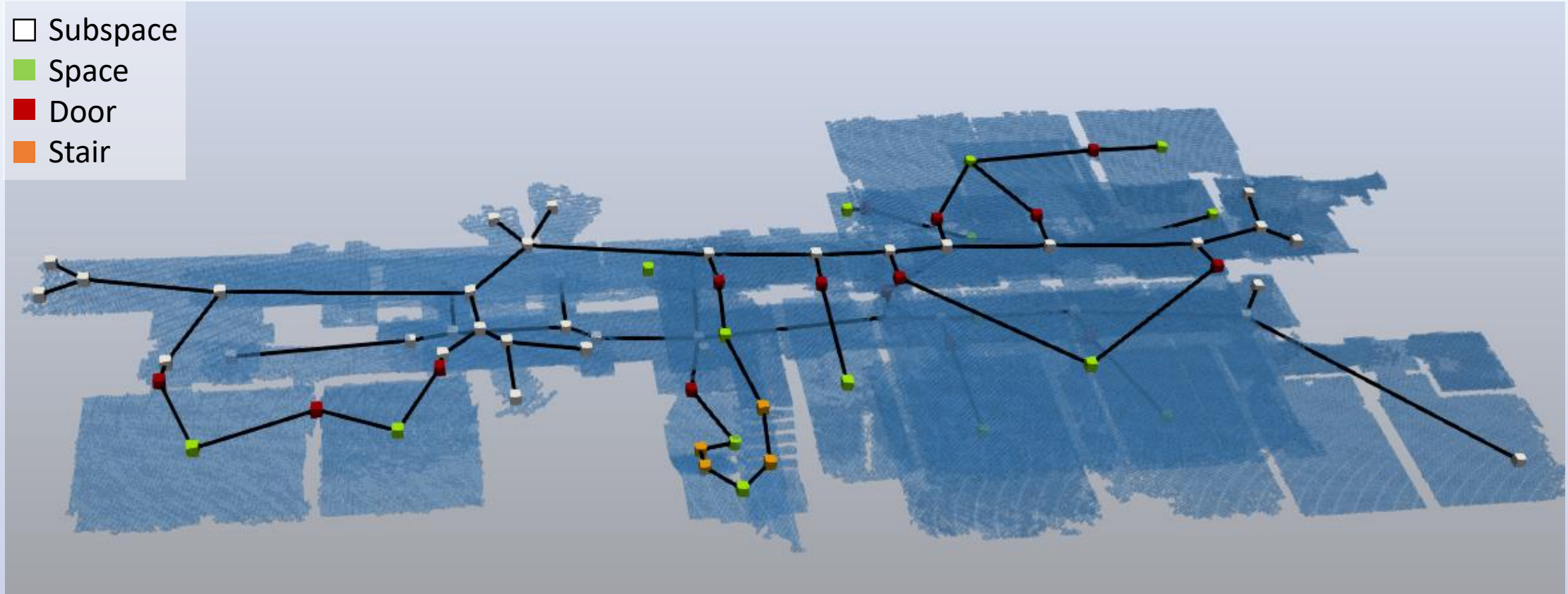


# Accessibility: door dimensions

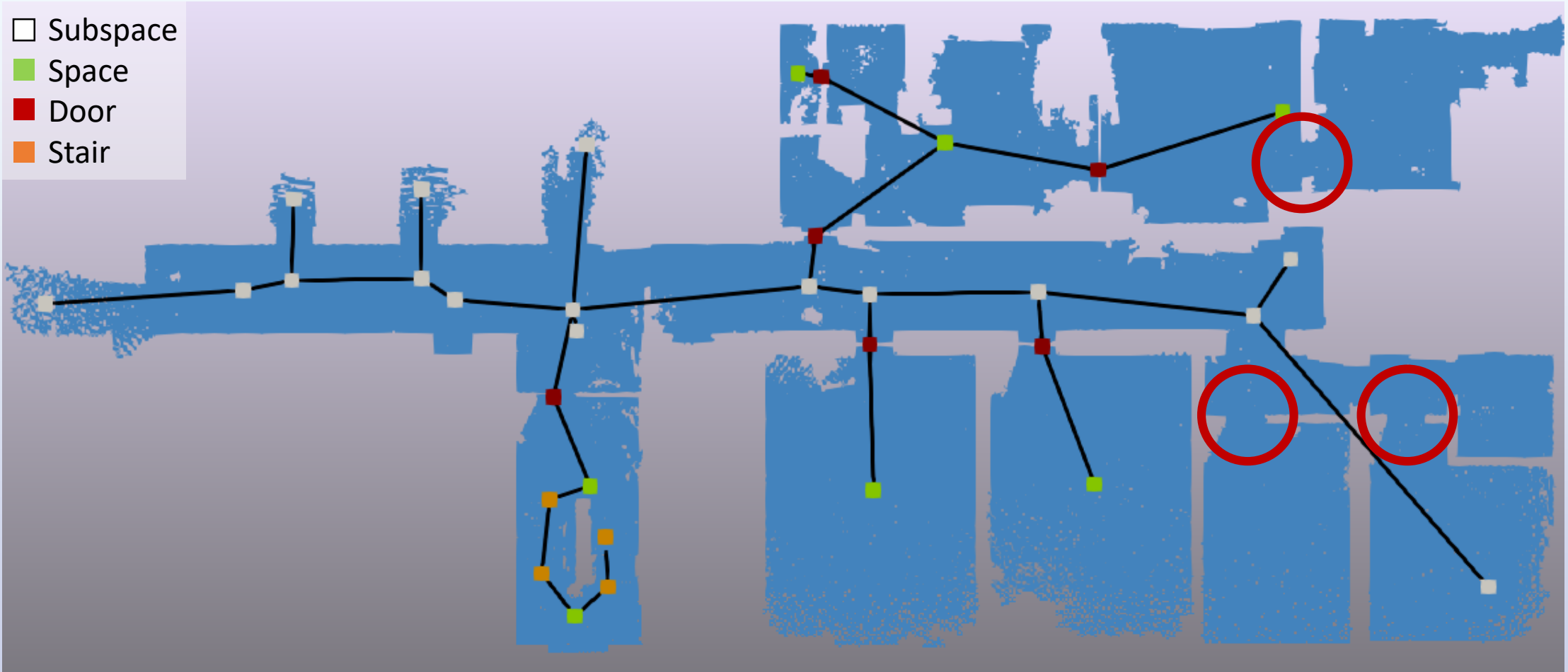


# Results & analysis

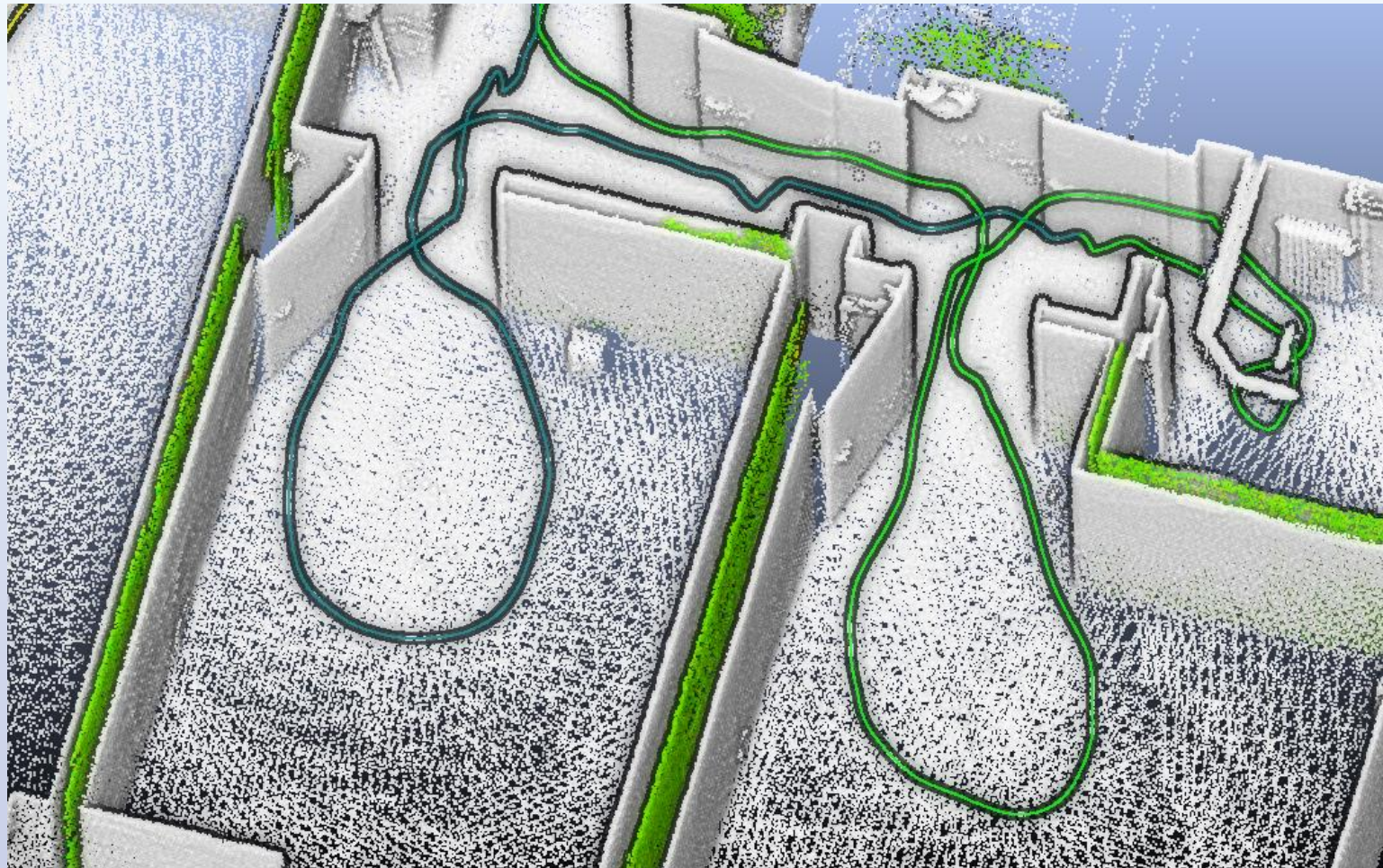
# Results on test point cloud



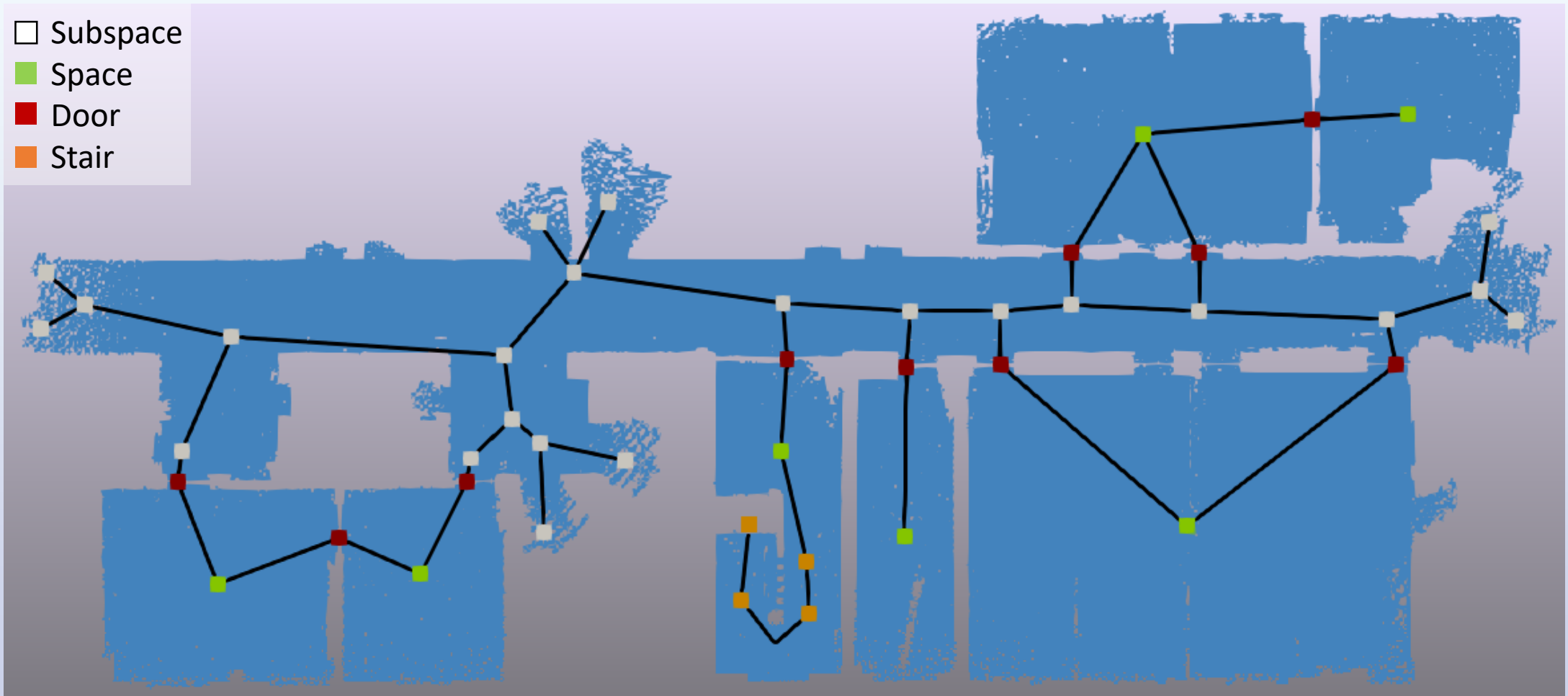
# Floor 1



# Not all doors were detected



# Floor 2

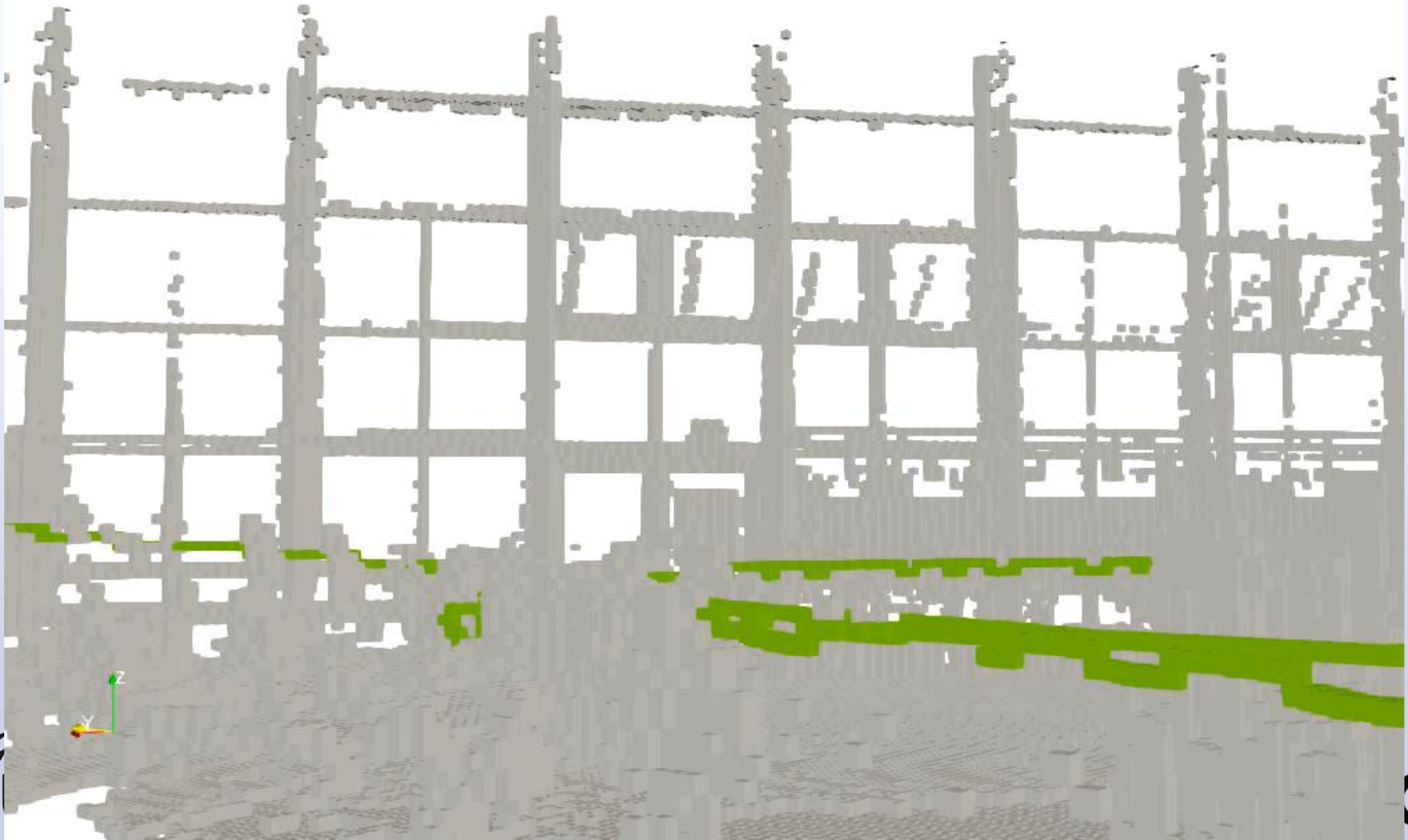


# Accessibility

- Some doors found to be 1.8 m high
- Could be caused by measurement error



# Conclusions





# Research objective

***Automatically extracting a navigation network in IndoorGML format from a cluttered indoor point cloud and its trajectory***



# What information could be retrieved?

- Doors
- Stairs & ramps
- Spaces (rooms, corridors, halls)
- Connectivity
- Accessibility (stairs, width & height of doors)



# Door detection

- Used for **separating** rooms
- Only doors that are walked through can be detected
- **100% detection rate** in development point cloud
- Sideways-looking method: still needs some work
  - Apply on point cloud instead of medial sheets?



# Subdivision of spaces

- Application of MAT successful in corridors
- More than one centre line in wide open spaces
  - Other methods needed

# Discussion & contribution

- Point cloud to navigation network
- 3D MAT: new method for wall detection in a point cloud

# Future work

- All doors to be detected
- Find method for subdividing large open spaces
- Write results to IndoorGML file
- Create navigation application that uses IndoorGML



Questions?

# Figures

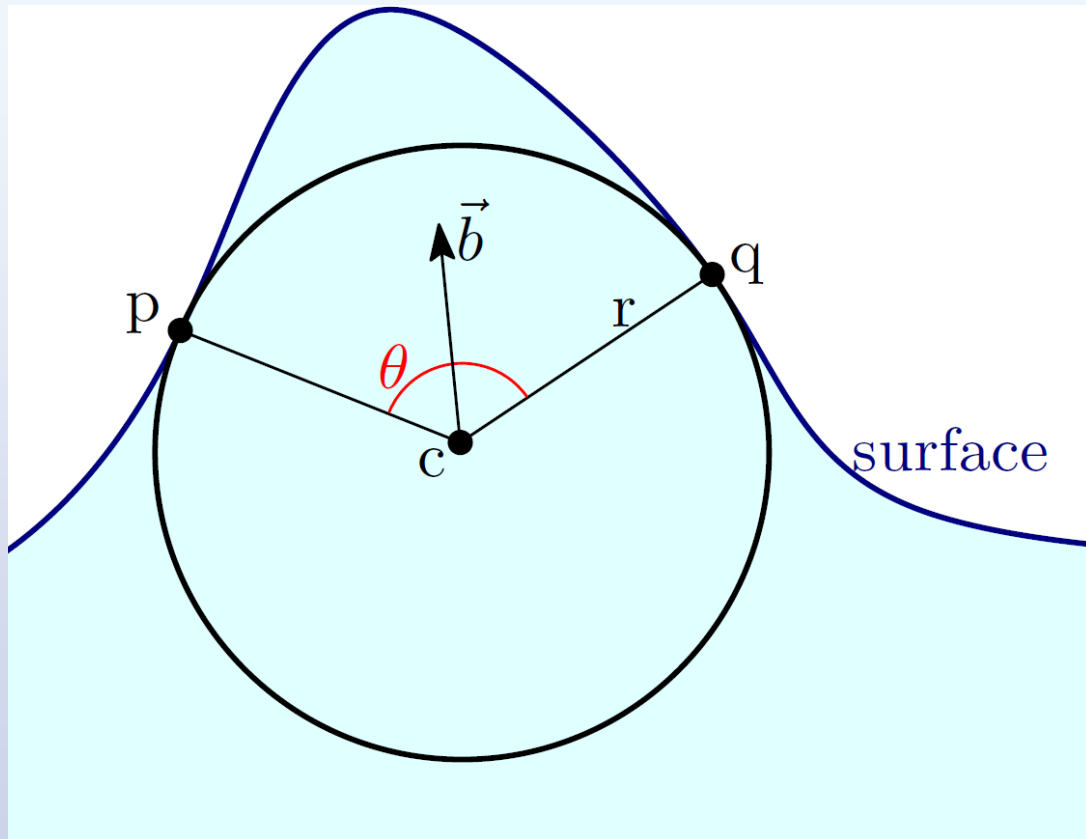
- Slide 5 (dense city): [Steven Wei](#)
- Slide 6 (wayfinding): [Studio Matthews](#)
- Slide 7 (wheelchair): [Karman Healthcare](#)
- Slide 7 (blind person): [Society for the Blind](#)
- Slide 8 (wayfinding): [Sign by Access](#)
- Slide 11 (ZEB REVO): [Geoslam](#)
- Slide 15 (door): [Murphy door](#)
- Slide 15 (stairs): [Howard Davis](#)
- Slide 18,19 (walkable space): (Staats, 2017)
- Slide 20 (medial axis): (Peters, 2018)
- Slide 21 (3D MAT): [Tyler Casella](#)

# References

- Peters, R. (2018). Geographical point cloud modelling with the 3D medial axis transform. PhD thesis, TU Delft.
- Staats, B. (2017). Identification of walkable space in a voxel model, derived from a point cloud and its corresponding trajectory. Master's thesis, TU Delft.

# 3D MAT wall sheet parameters

Theoretical



Inside a wall

