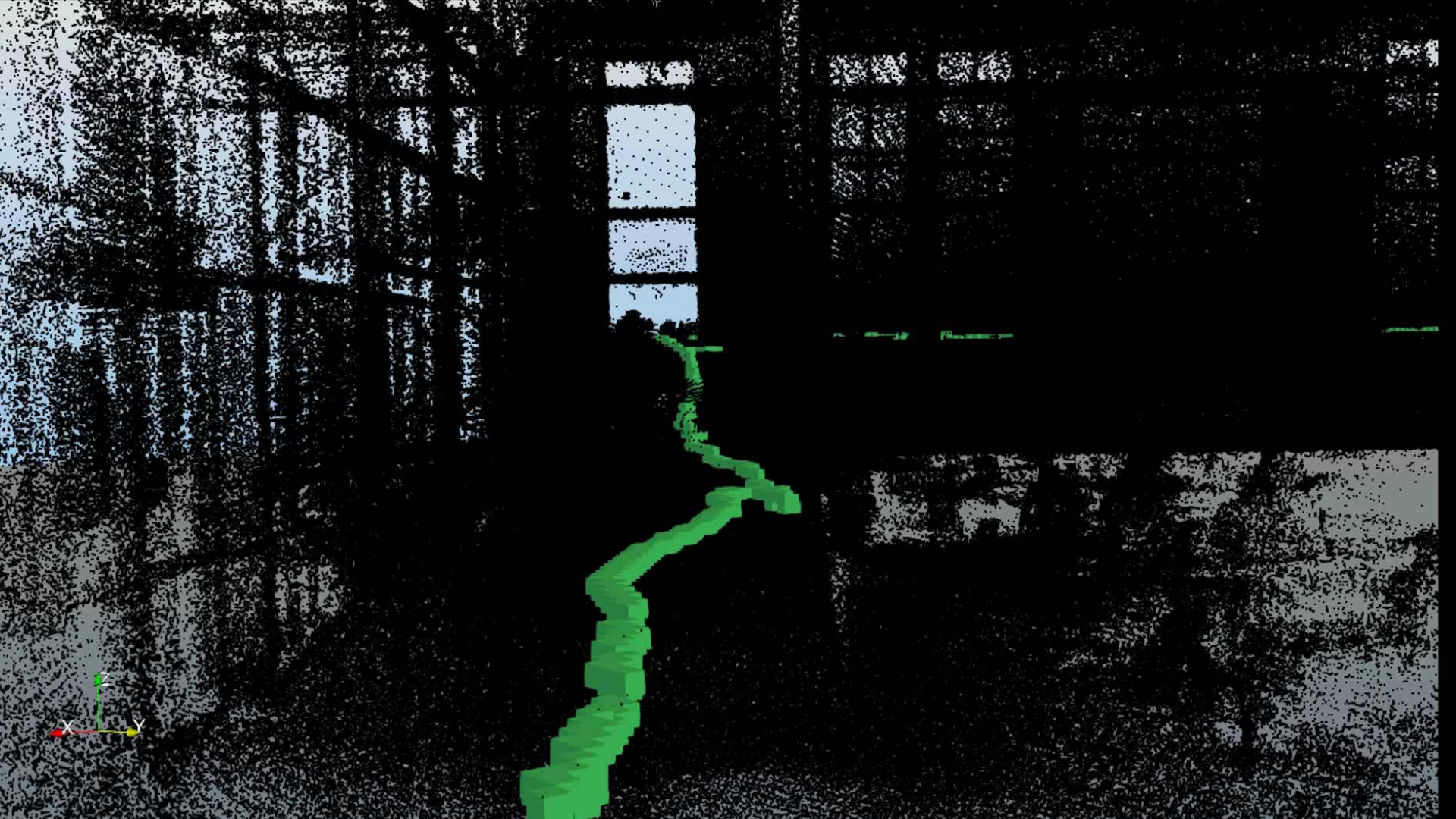
Z
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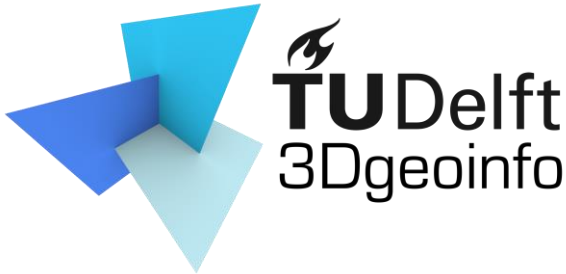
Identification of walkable space in a voxel model, derived from a point cloud and its corresponding trajectory

Bart Staats

P5

July 5th 2017

In collaboration with



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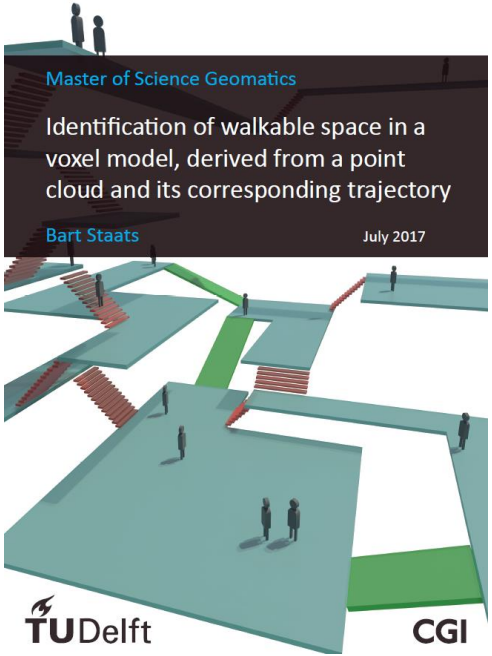


AUTOMATIC GENERATION OF INDOOR NAVIGABLE SPACE USING A POINT CLOUD AND ITS SCANNER TRAJECTORY

B. R. Staats[a], A. A. Diakite[b], R. L. Voûte[c,d], S. Zlatanova[b,*]

[a] Master of Science Geomatics, Faculty of Architecture and the Built Environment, TU Delft, The Netherlands – b.r.staats@student.tudelft.nl
[b] 3D Geo-Informatie, Faculty of Architecture and the Built Environment, TU Delft, The Netherlands - (a.a.diakite, s.zlatanova)@tudelft.nl
[c] Department of Urbanism, Faculty of Architecture and the Built Environment, TU Delft, The Netherlands - r.voute@tudelft.nl
[d] CGI Nederland BV, The Netherlands – robert.voute@cgi.com

KEY WORDS: Navigation space, MLS, Floorplan, Indoor, Trajectory, Voxel, Dynamic objects, 3D laser scanning

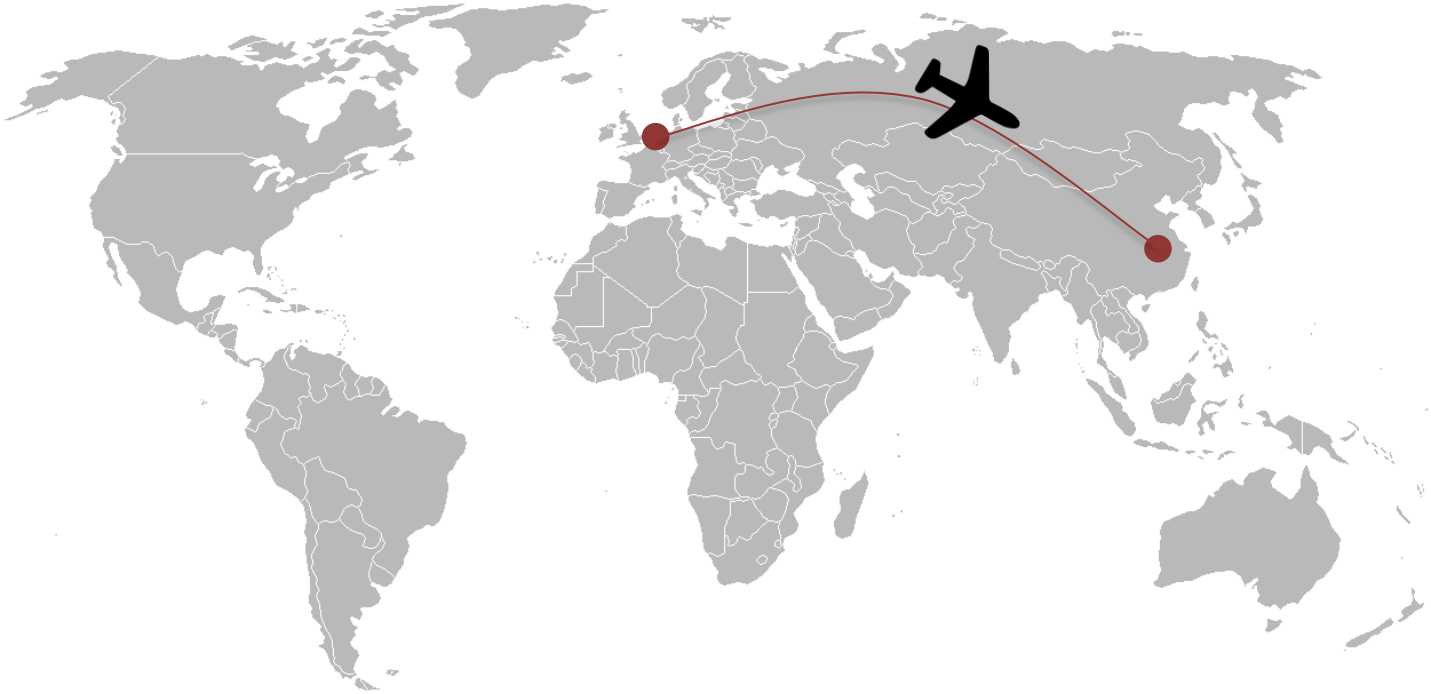
ABSTRACT:

Automatic generation of indoor navigable models is mostly based on 2D floor plans. However, in many cases the floor plans are out of date. Buildings are not always built according to their blue prints, interiors might change after a few years because of modified walls and doors, and furniture may be repositioned to the user's preferences. Therefore, new approaches for the quick recording of indoor environments should be investigated. This paper concentrates on laser scanning with a Mobile Laser Scanner (MLS) device. The MLS device stores a point cloud and its trajectory. If the MLS device is operated by a human, the trajectory contains information which can be used to distinguish different surfaces. In this paper a method is presented for the identification of walkable surfaces based on the analysis of the point cloud and the trajectory of the MLS scanner. This method consists of several steps. First, the point cloud is voxelized. Second, the trajectory is analysing and projecting to acquire seed voxels. Third, these seed voxels are generated into floor regions by the use of a region growing process. By identifying dynamic objects, doors and furniture, these floor regions can be modified so that each region represents a specific navigable space inside a building as a free navigable voxel space. By combining the point cloud and its corresponding trajectory, the walkable space can be identified for any type of building even if the interior is scanned during business hours. Moons (1997)

1. INTRODUCTION

Navigation from a room inside a building to a room inside another building across the street consists of three parts: a first indoor part in the building where you start your journey, an outdoor part and a second indoor part in the destination building (?). In the outdoor environment, a navigation aid is well implemented and used in all according to their blue prints, interiors might change after a few years by modification of walls and doors and furniture may be repositioned to the users preferences. Therefore, new approaches for the efficient 3D recording of indoor environments should be investigated. This paper concentrates on the automatic generation of indoor navigable space for pedestrians based on laser scanning with a Mobile Laser Scanner (MLS) device. These de-

Thesis + paper



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Content

1. Problem statement
2. Research question
3. Method
4. Implementation
5. Results
6. Conclusion

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Navigation

Botanische tuin
KANAALWEG
MIJNBOUWSTRAAT
De Vries van Heijstplantsoen
RK begraafplaats Kanaalweg
Kanaalweg
JULIANALAAN
ZUIDPLANTSOEN
Schoemakerstraat
Michiel de Ruyterweg
PIET HEINSTRAAT
ROTTERDAMSEWEG
ZUIDWAL
Zuidwal
Kolk
HOOIKADE
ZUIDEINDE
SCHEEPMAKERIJ
OUDE DELFT
WESTVEST
ACHTEROM
Crommelinlaan
PLEIN DELFTZICHT

Indoor navigation system

- Indoor positioning system
- Indoor navigable map
- Specific destinations
- Appropriate guidance

Indoor navigation system

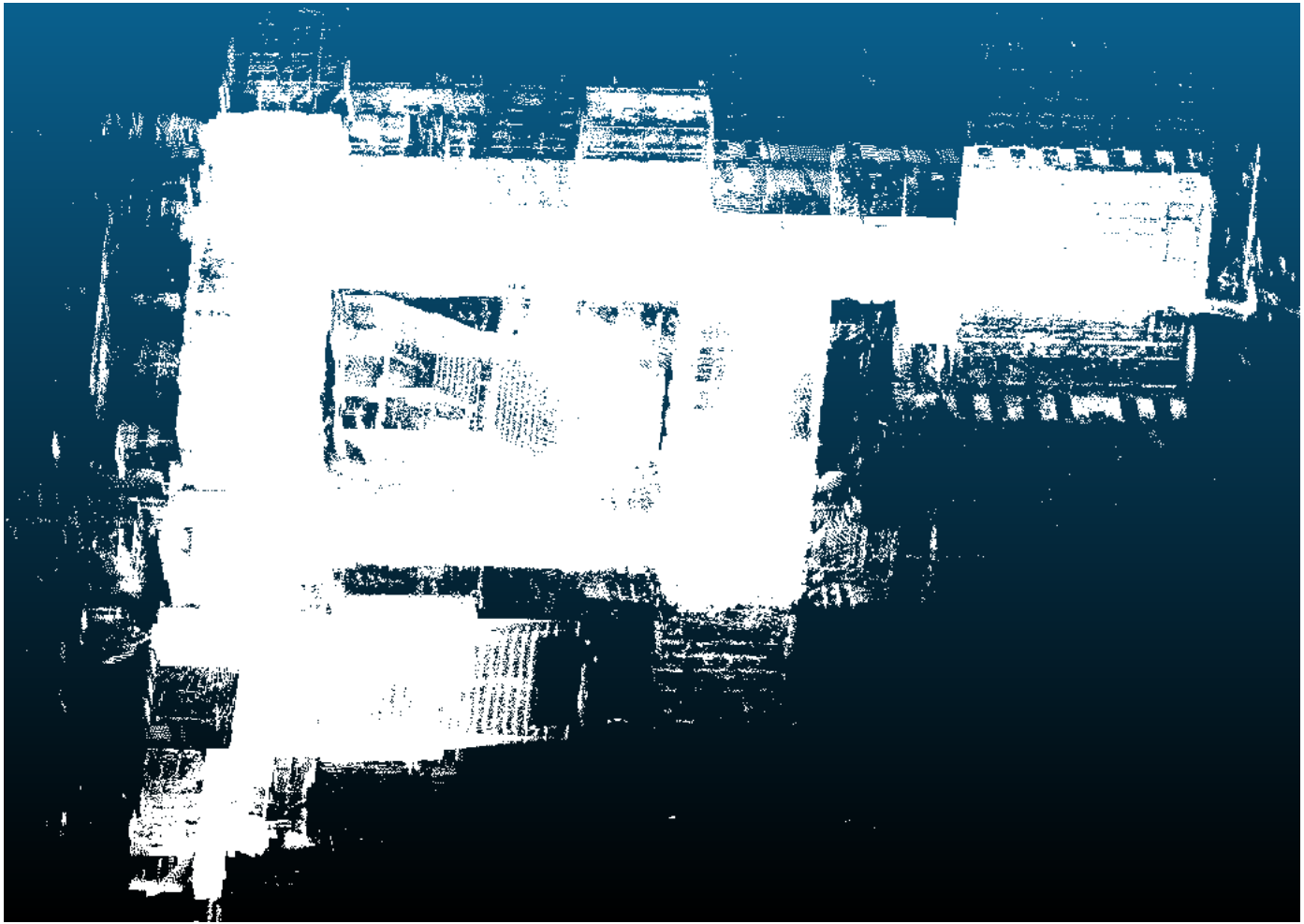
- Indoor positioning system
- **Indoor navigable map**
- Specific destinations
- Appropriate guidance

Floor plans

- A lot of research
- Floor plans are out of date
  - Not build according to blueprints
  - Interior changing over time (walls, doors)
  - Furniture missing
  - Connection between maps difficult

Point cloud

- A lot of research
- Methods:
  - Histogram, RANSAC and more
- Limitations
  - Manhattan world assumption
  - Only horizontal surfaces
- Need for a new method!



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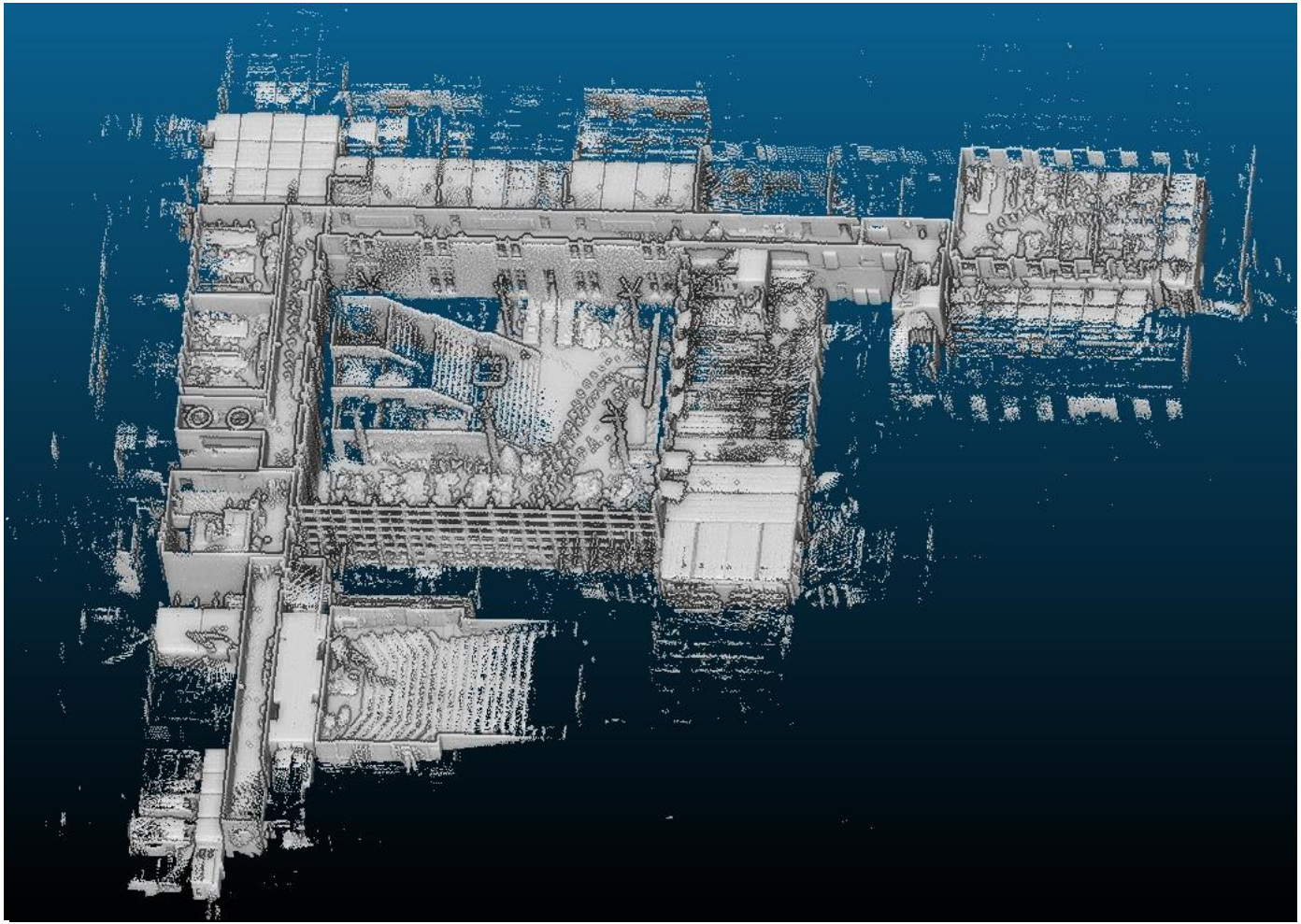

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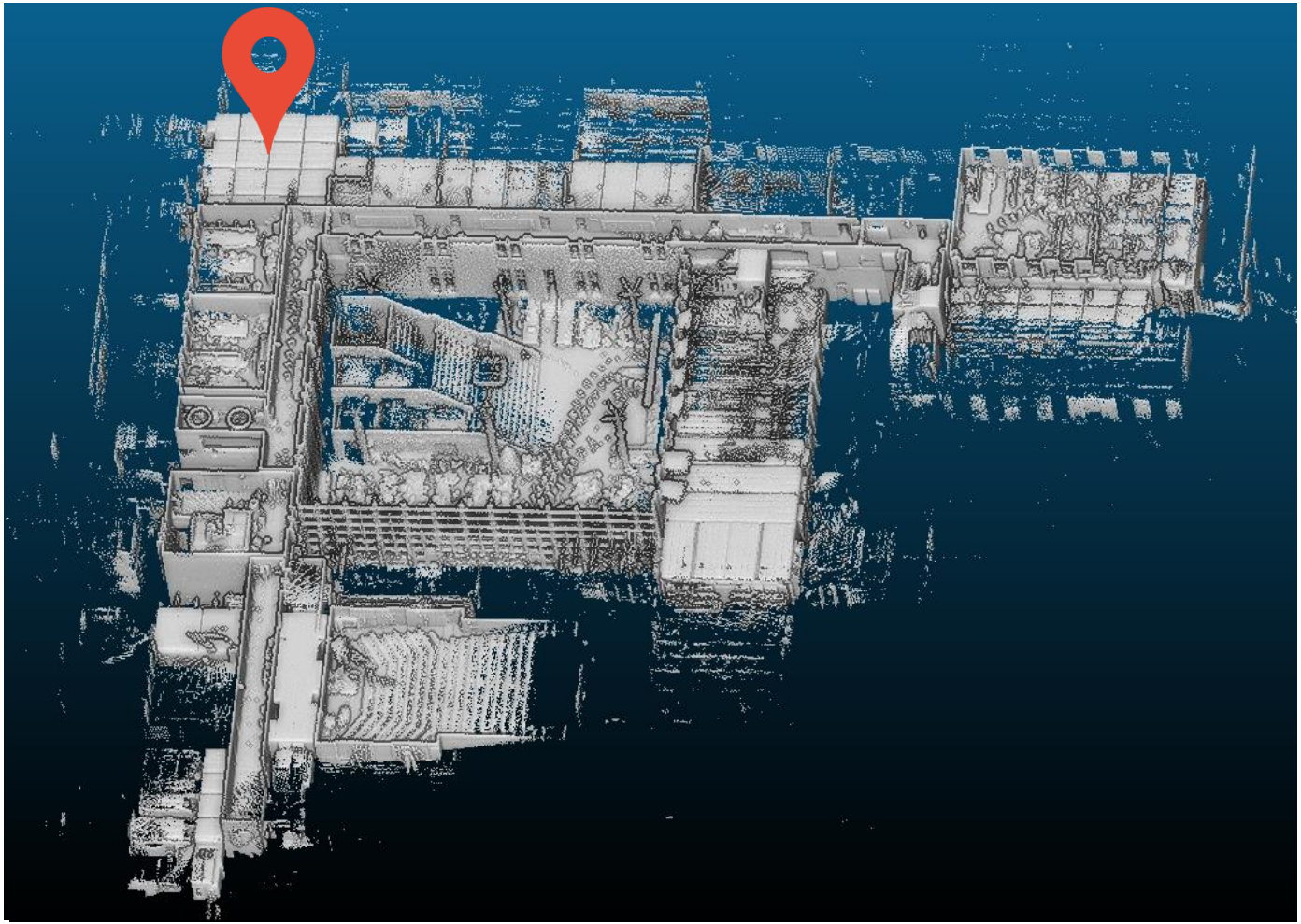

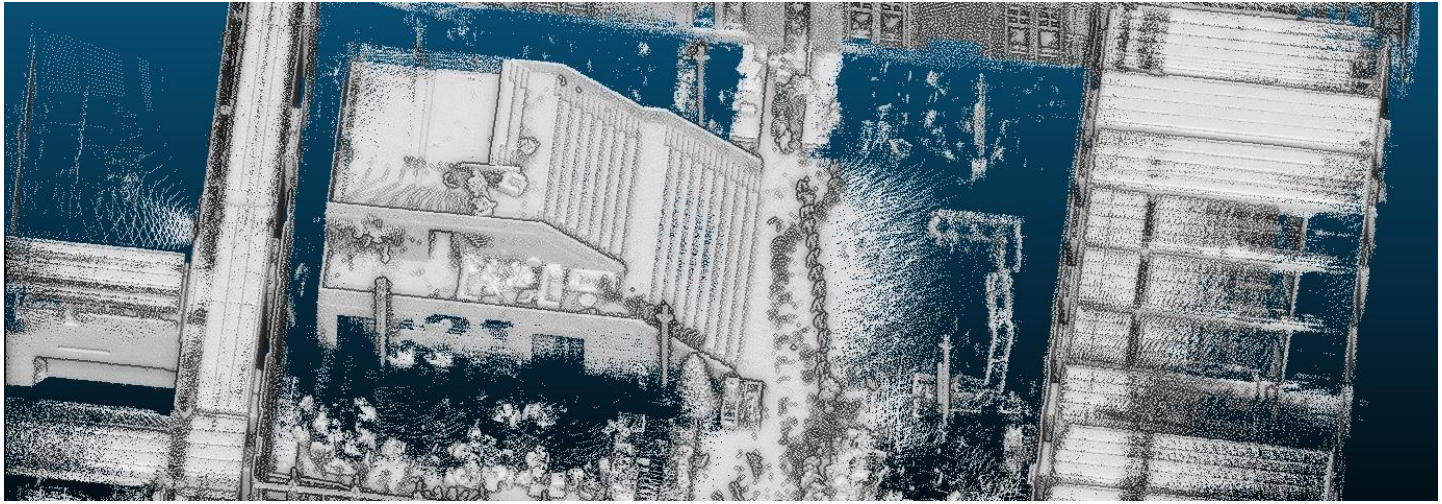

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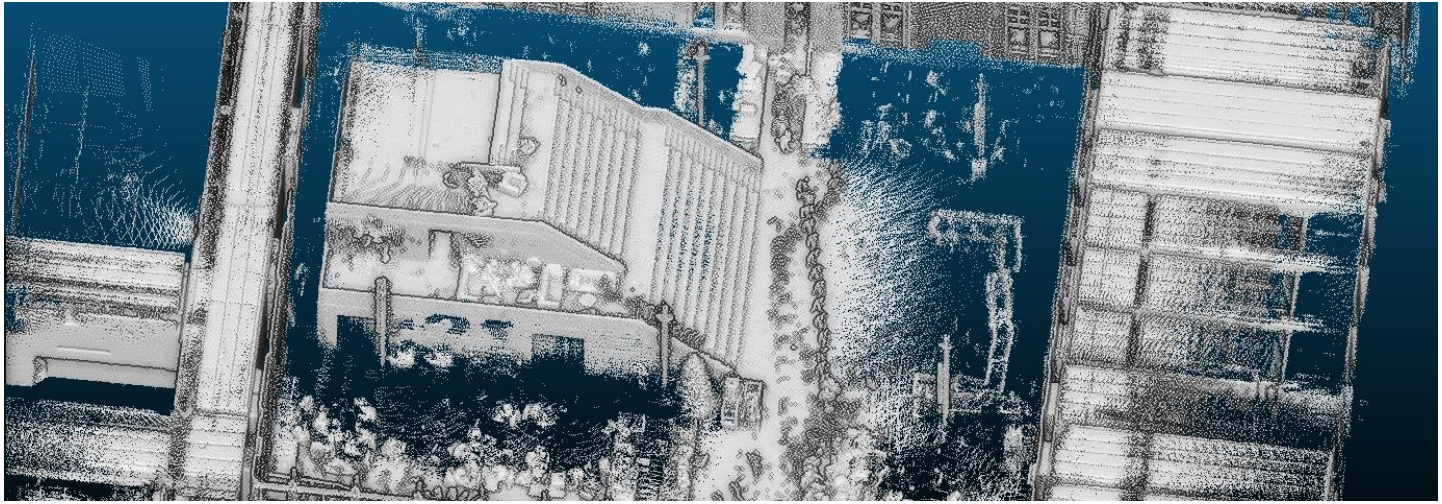

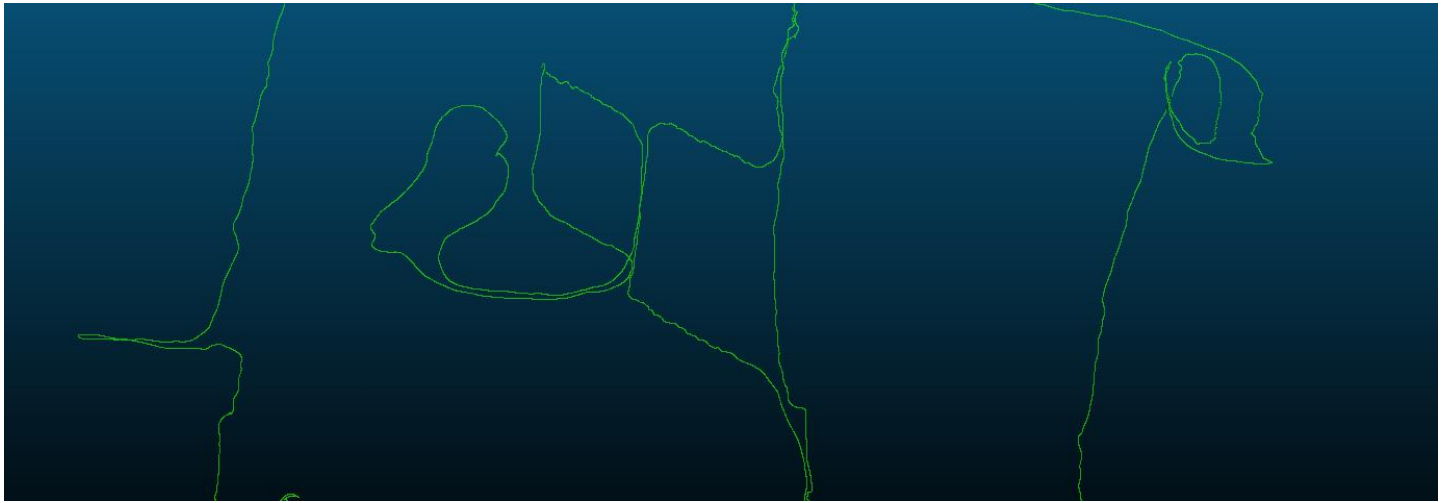

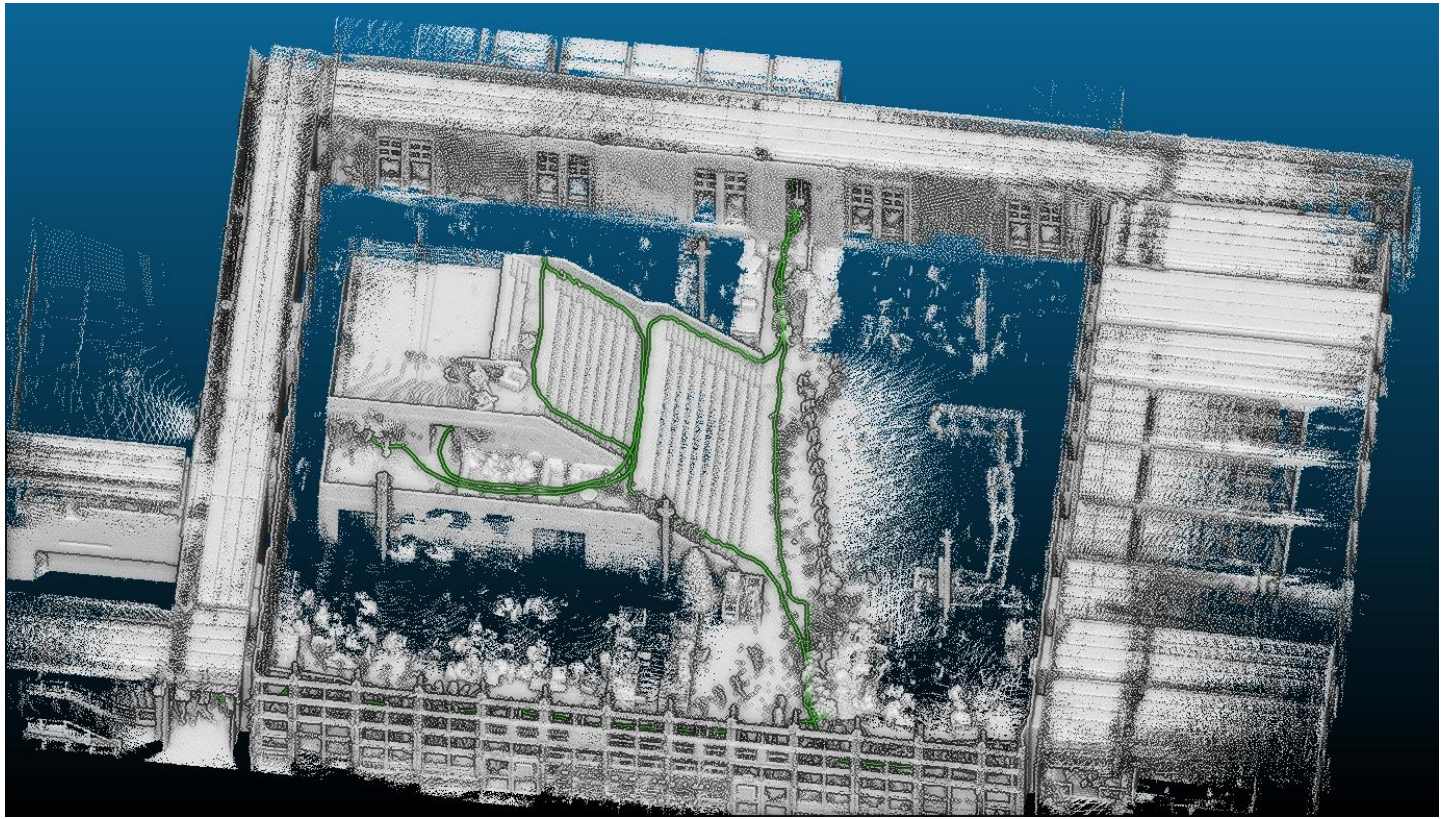

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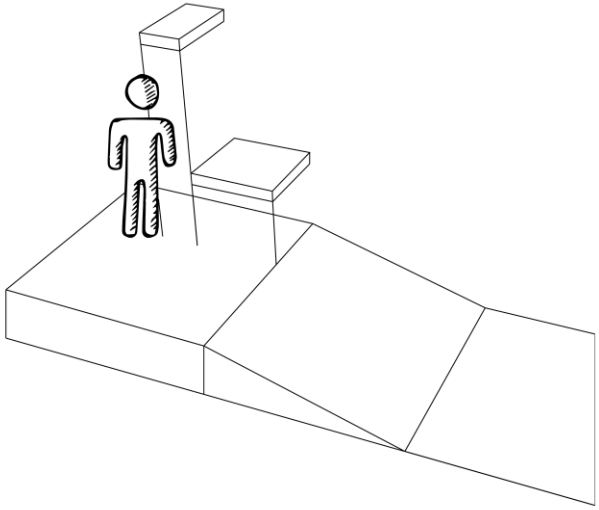
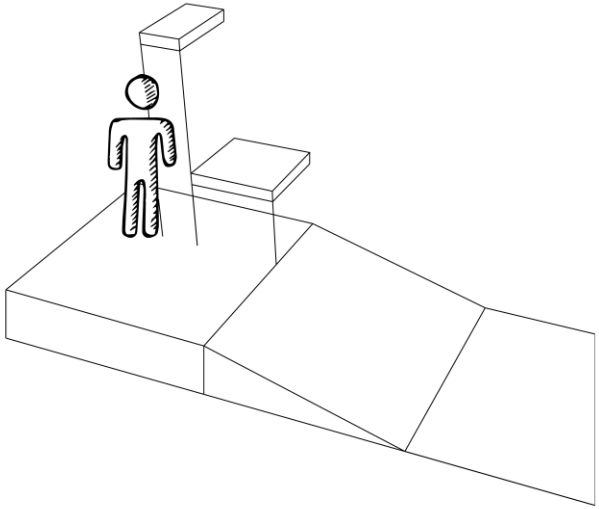
Research question

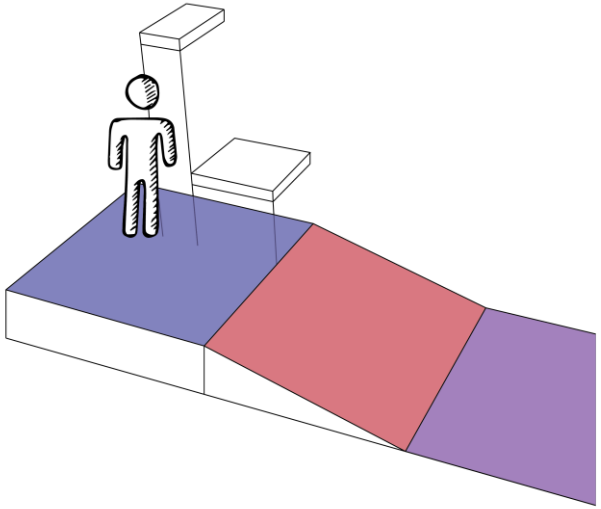
Which indoor **walkable space** can be identified from a **voxelized point cloud** using the **trajectory** of a mobile laser scanner?

Walkable space

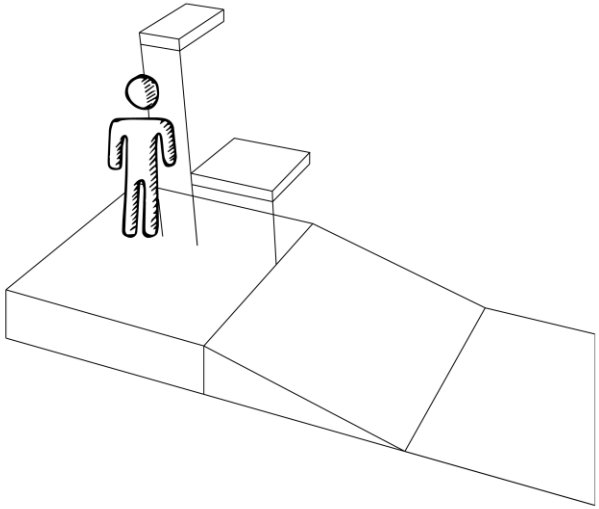


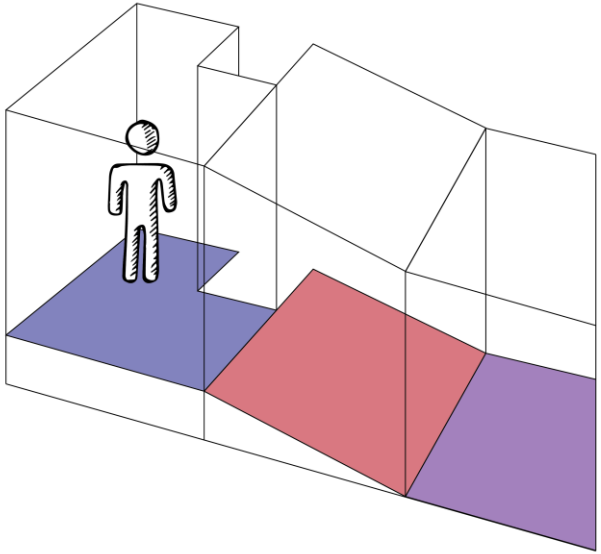
Walkable space



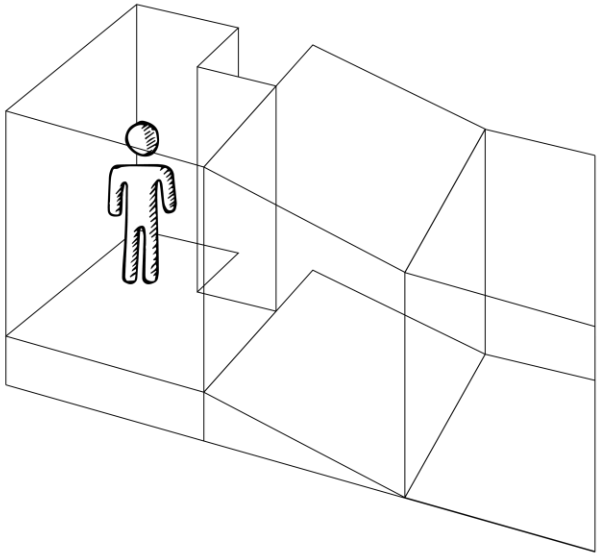


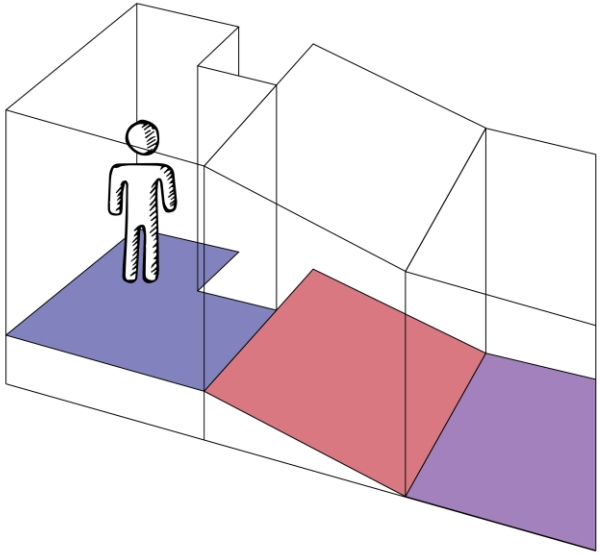
Walkable space



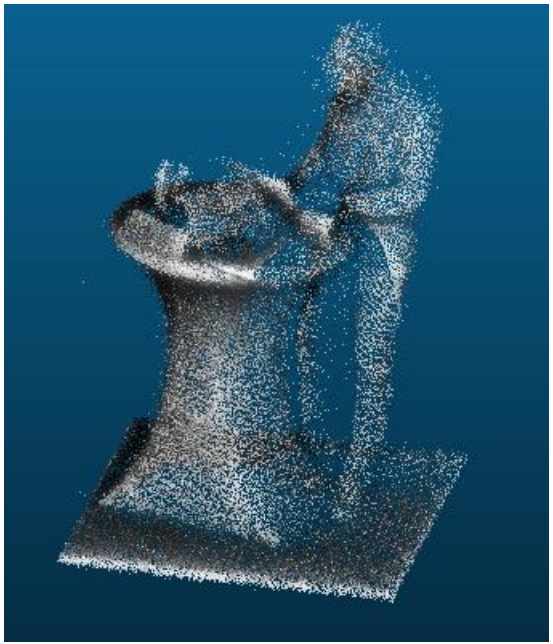


Walkable space





Voxel model



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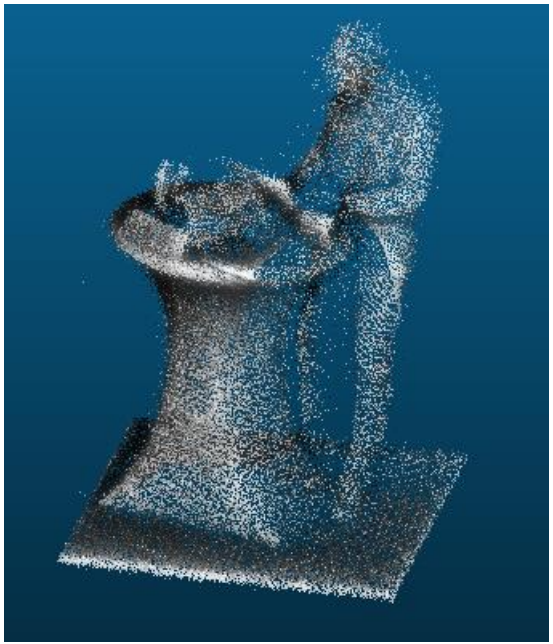

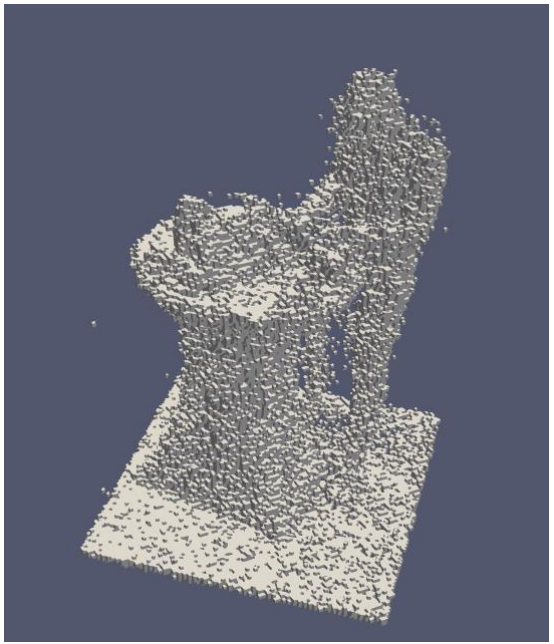

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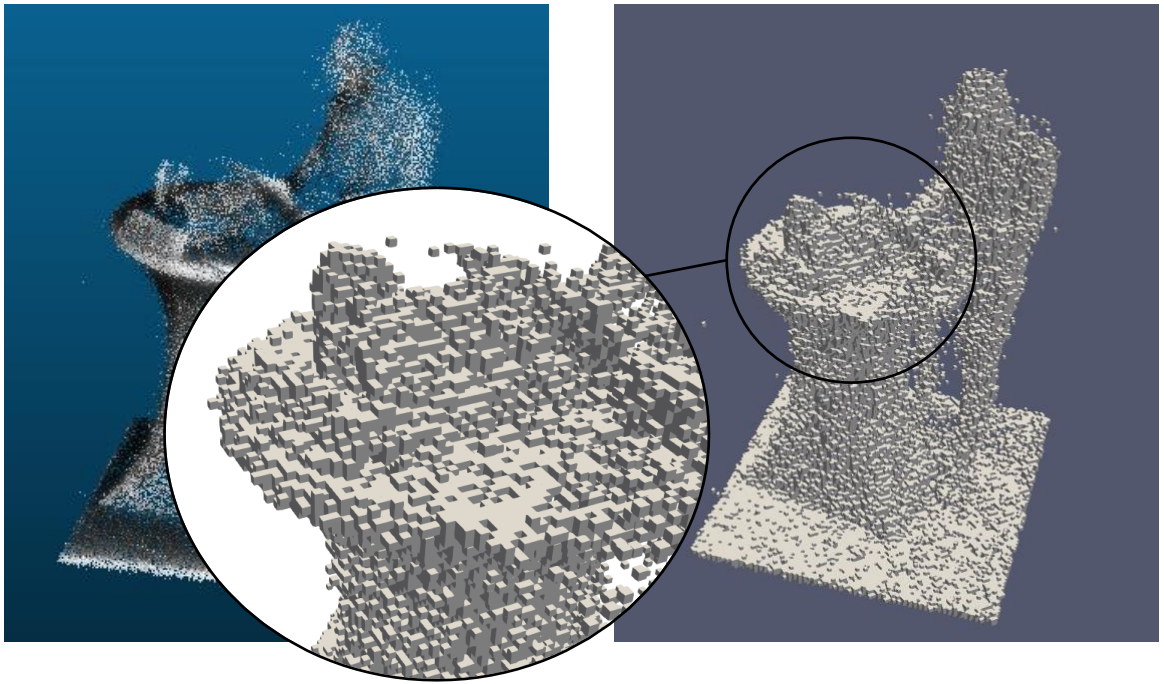
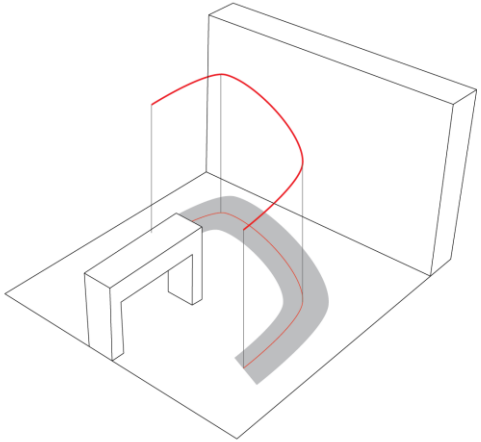
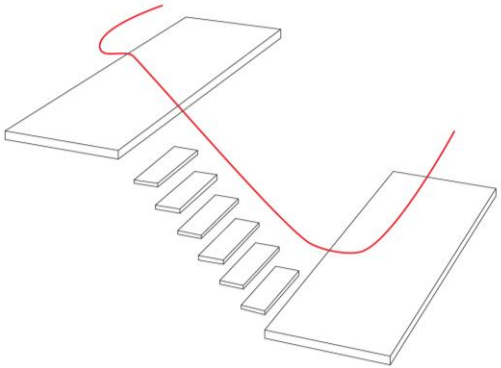


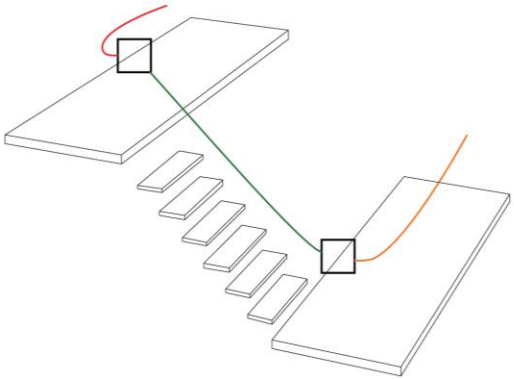
Trajectory information



Walkable points

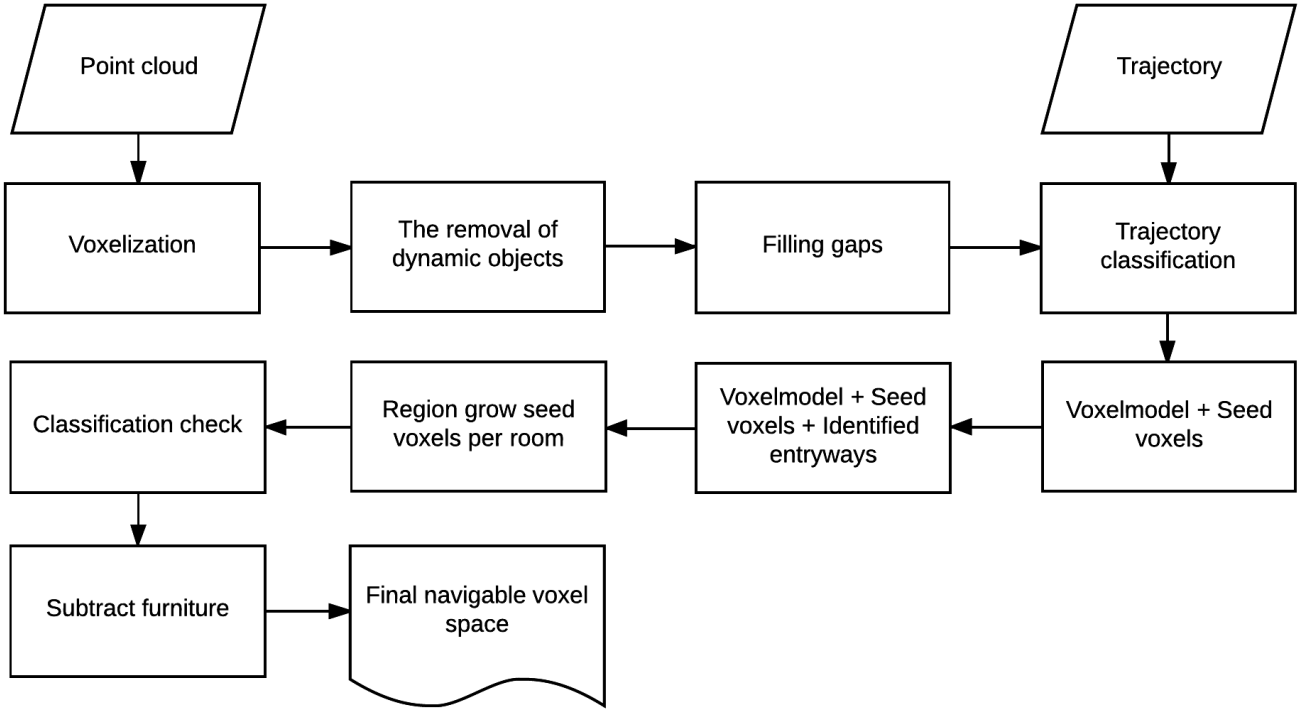


Stair detection



Connection information

Method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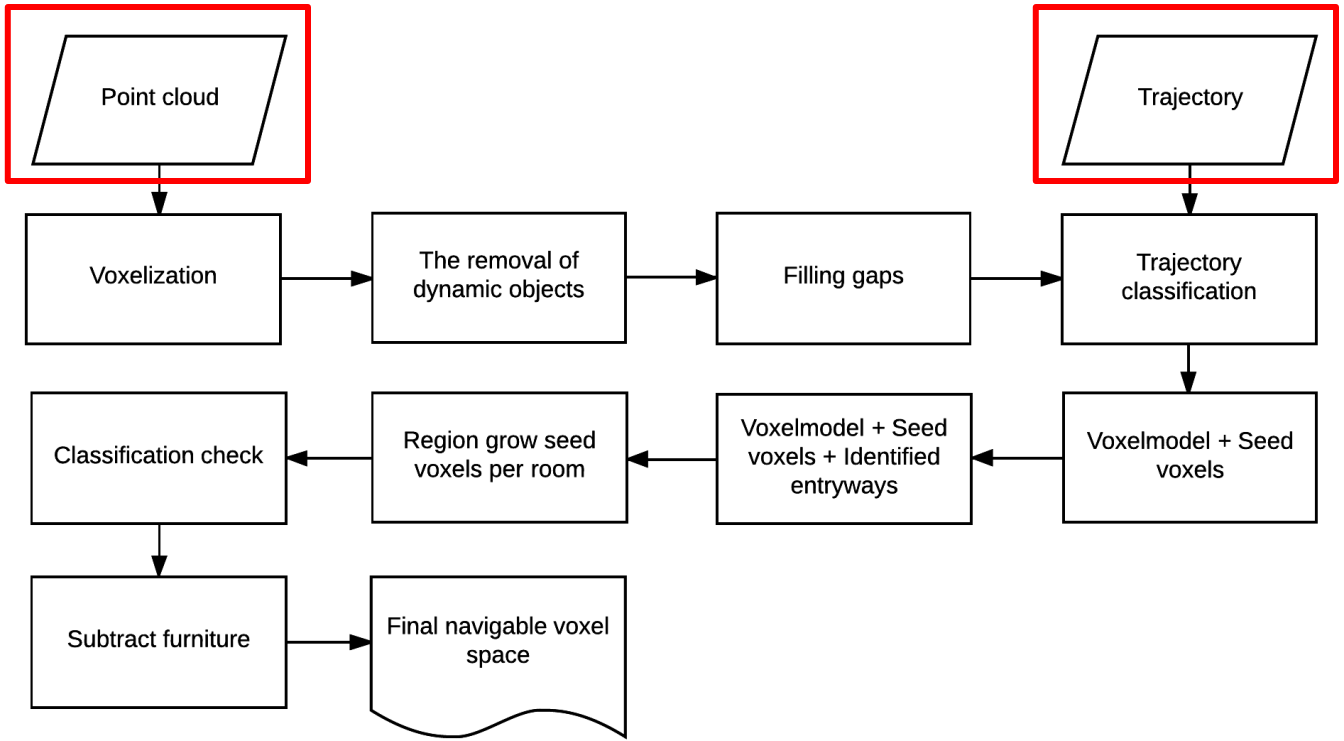
Subtract furniture
Final navigable voxel space

Method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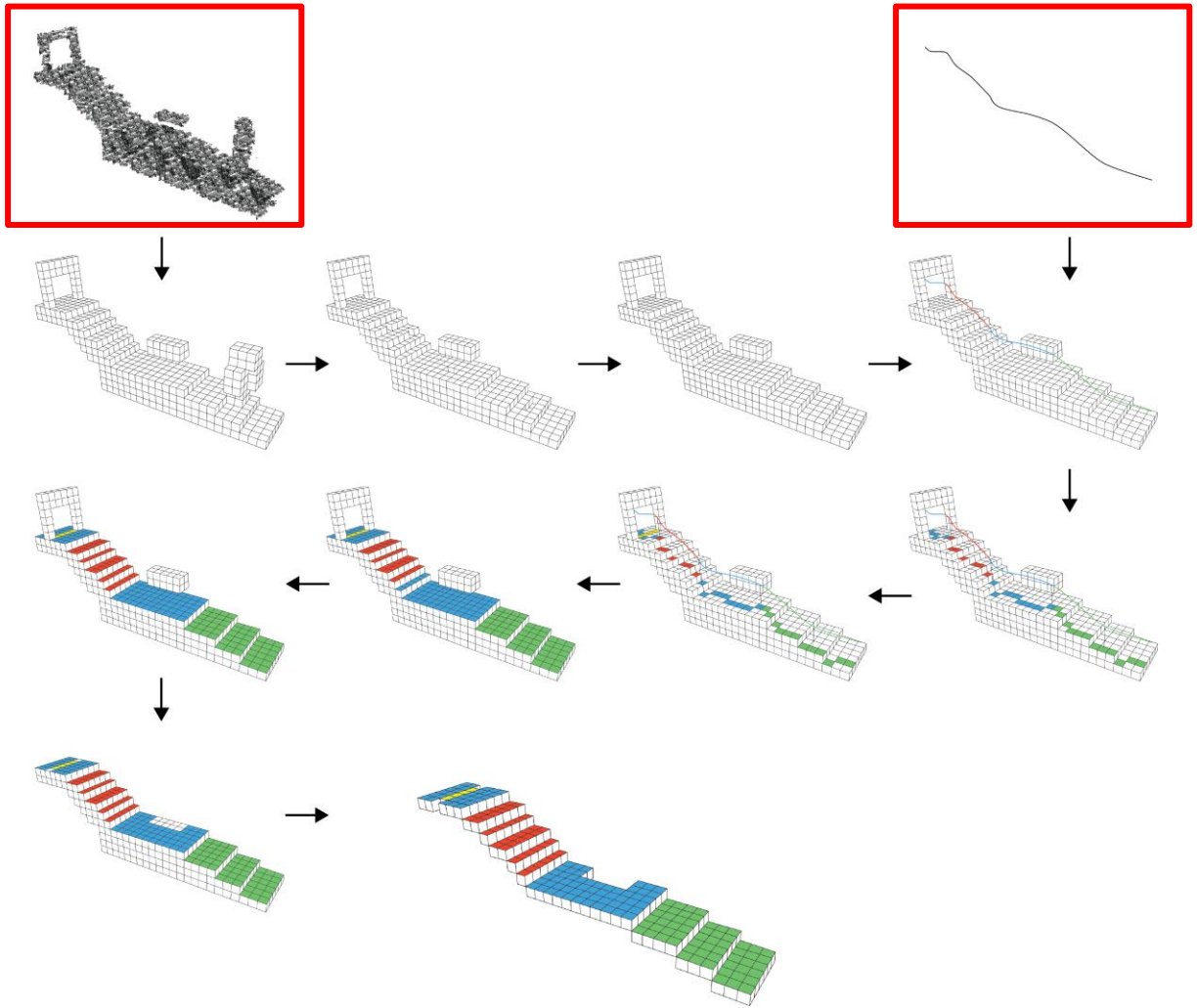

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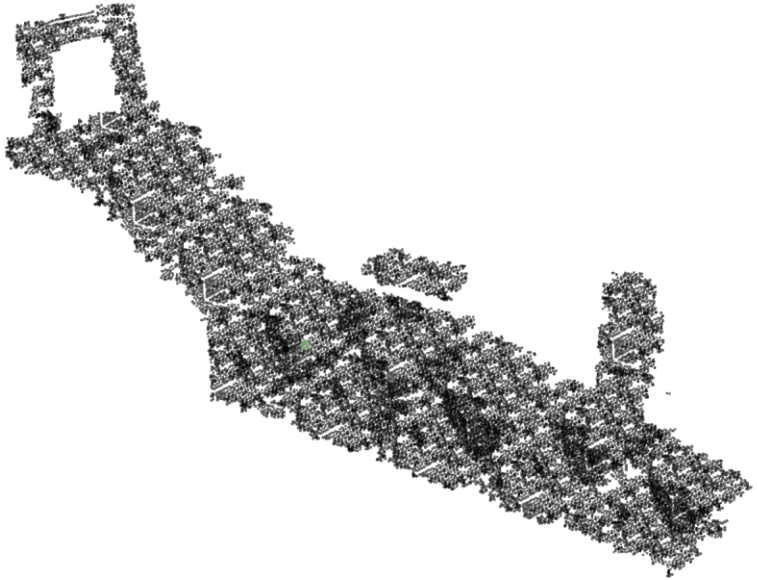

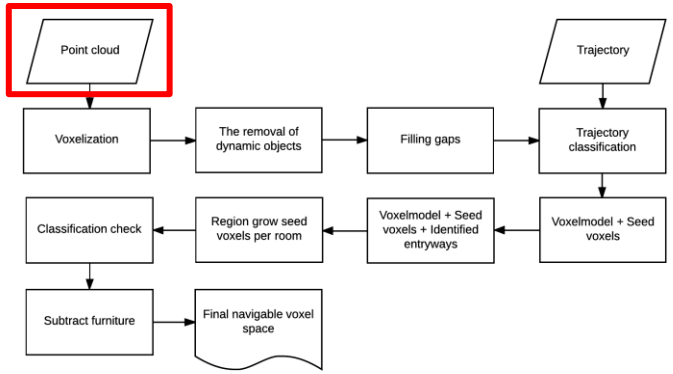
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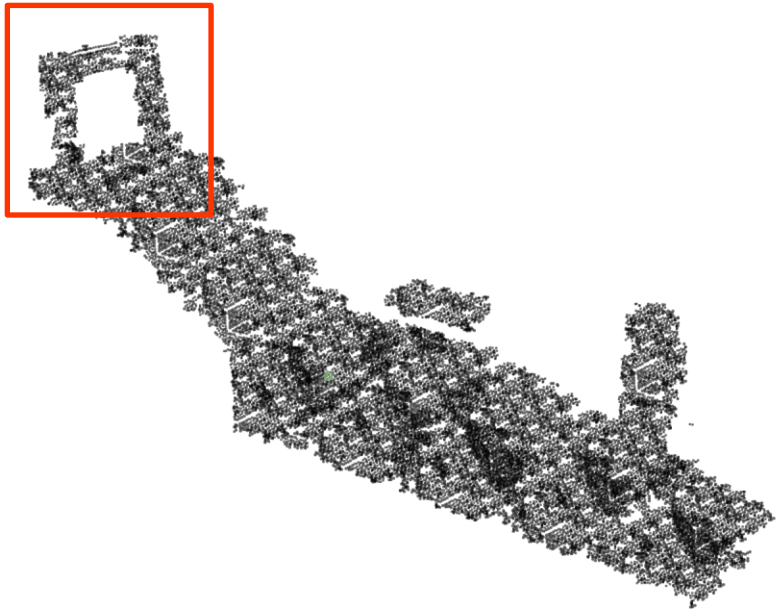

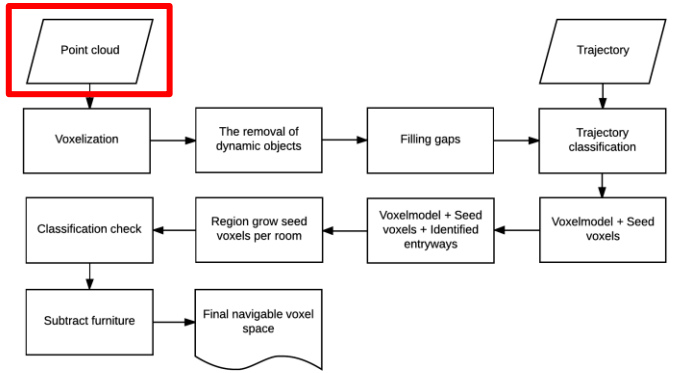
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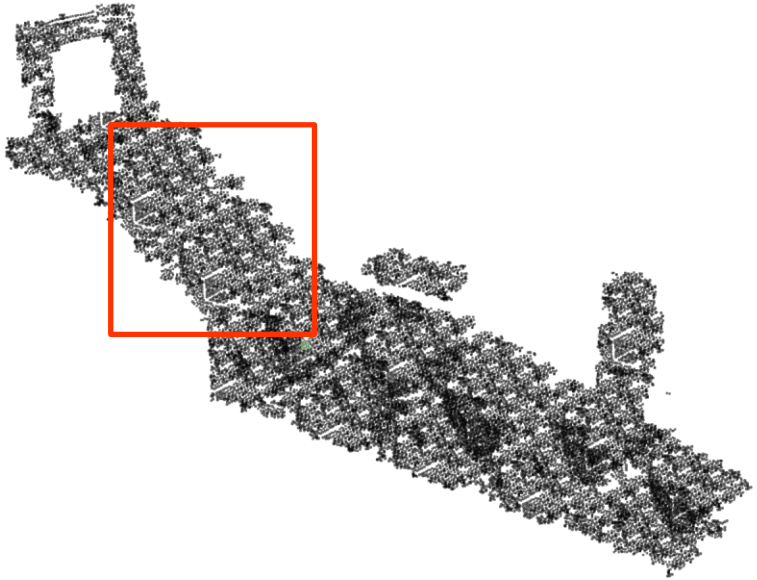

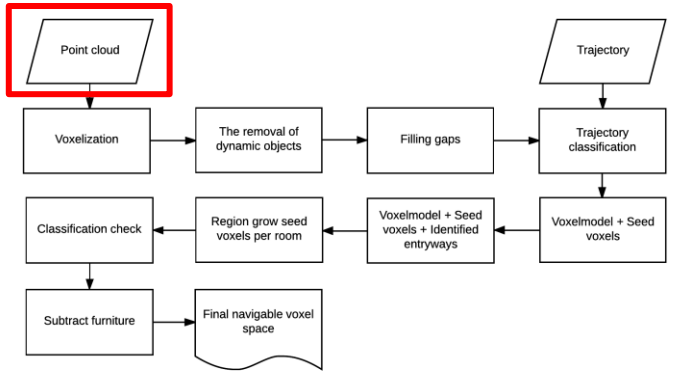
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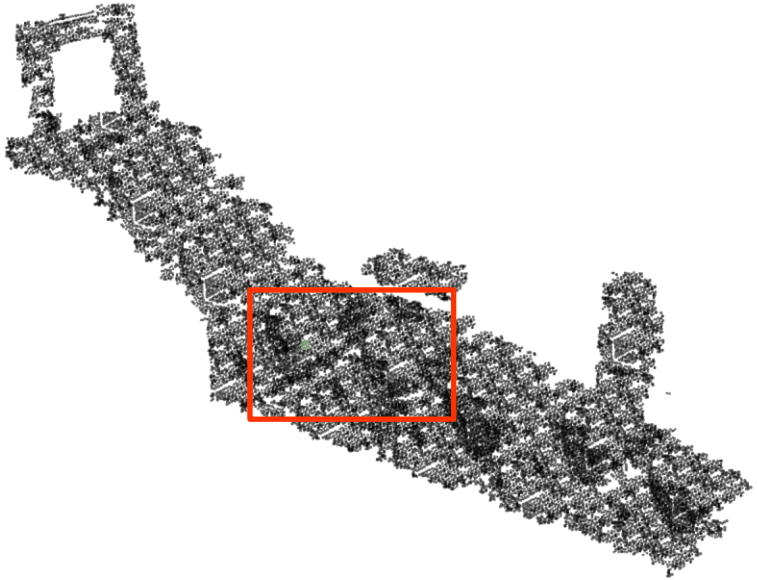

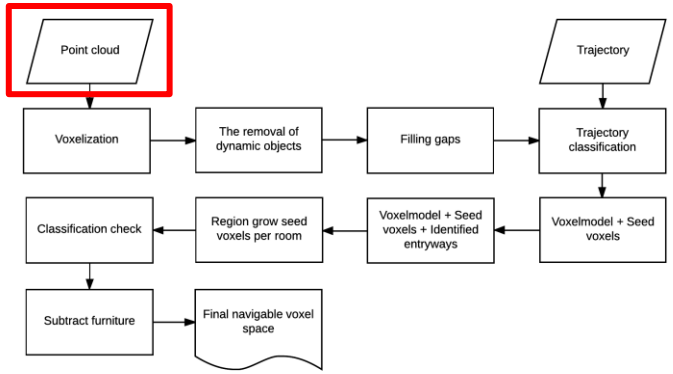
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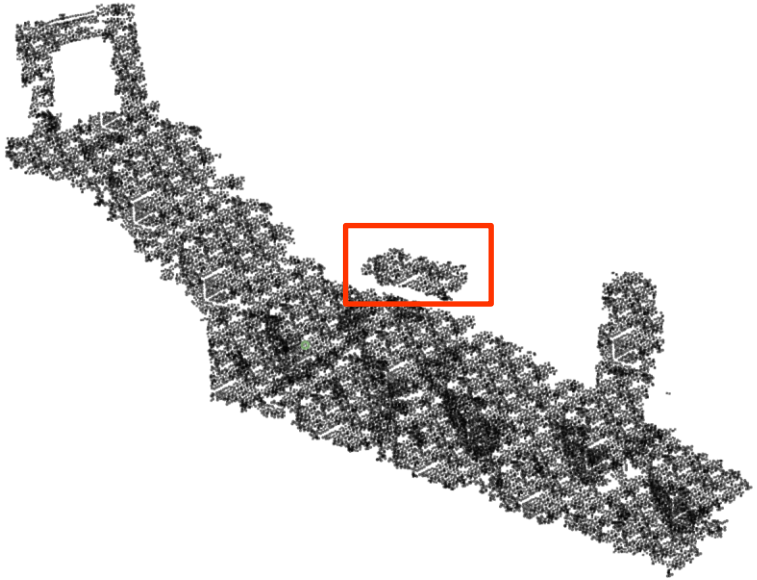

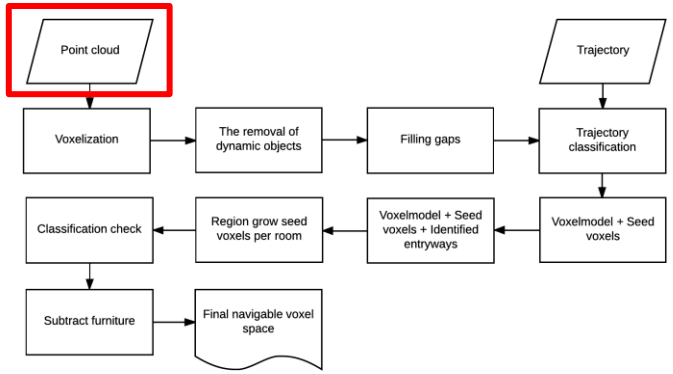
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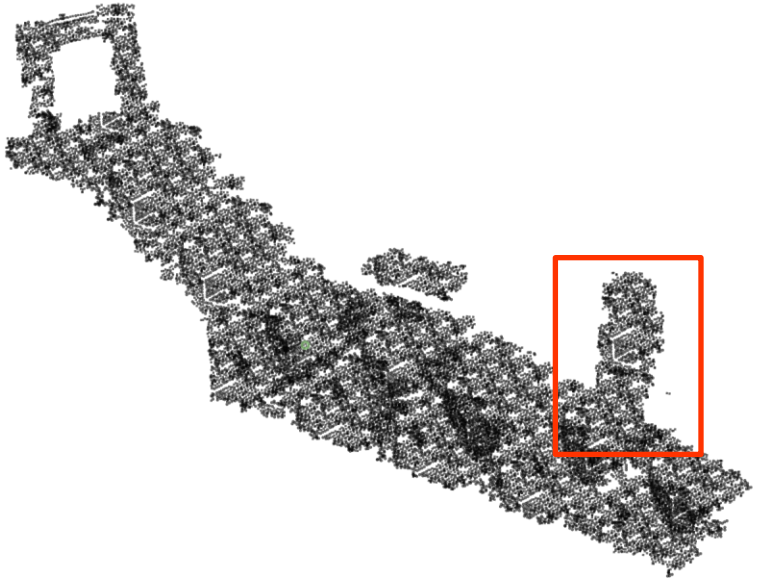

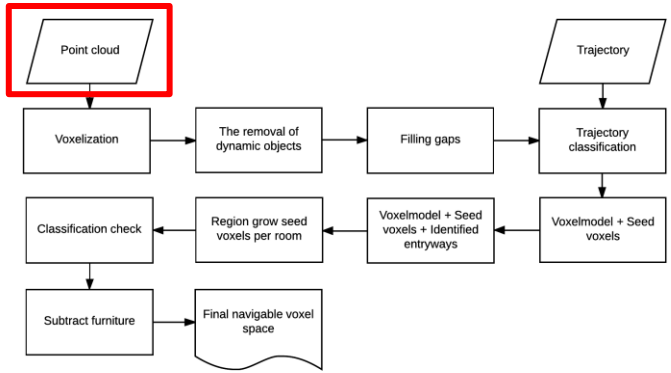
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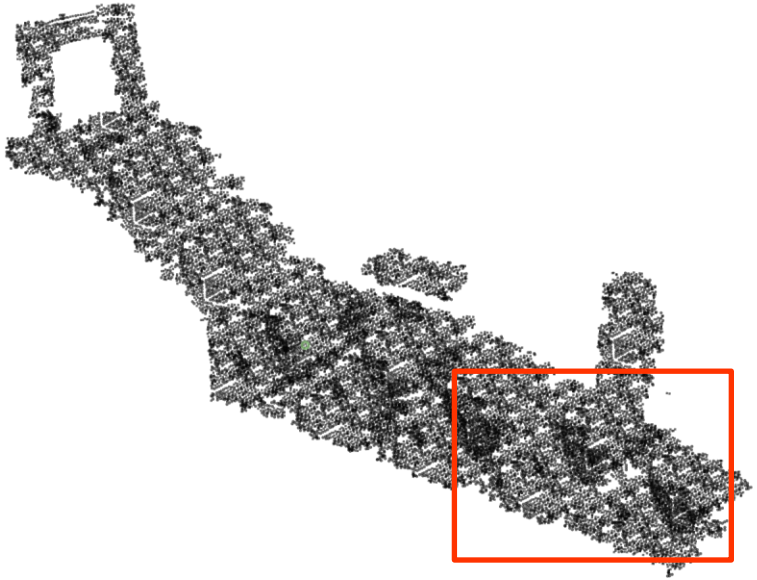

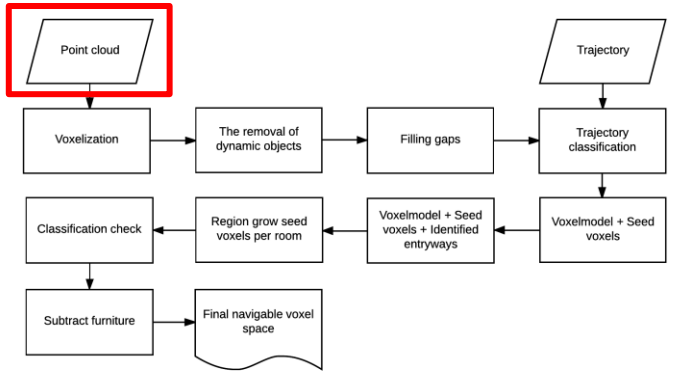
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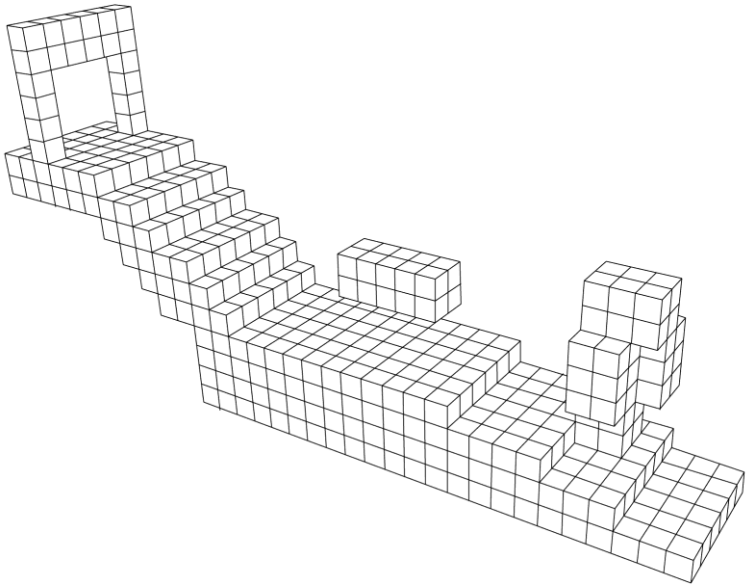

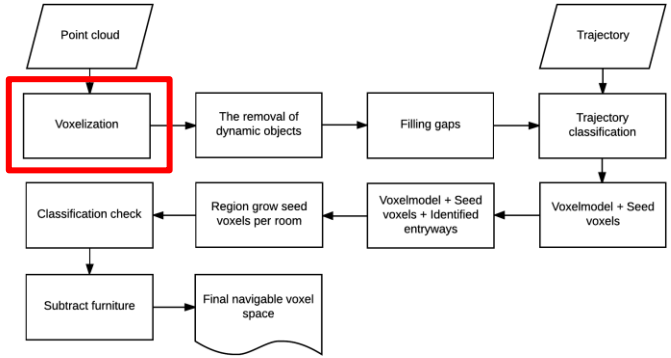
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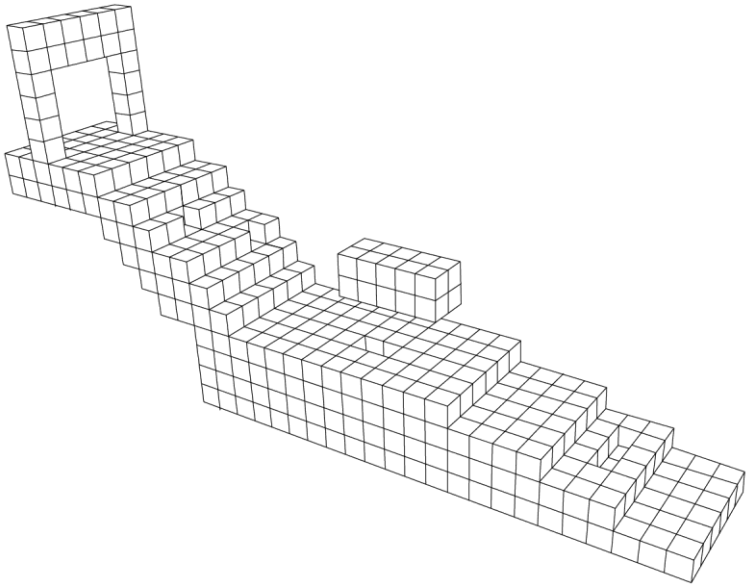

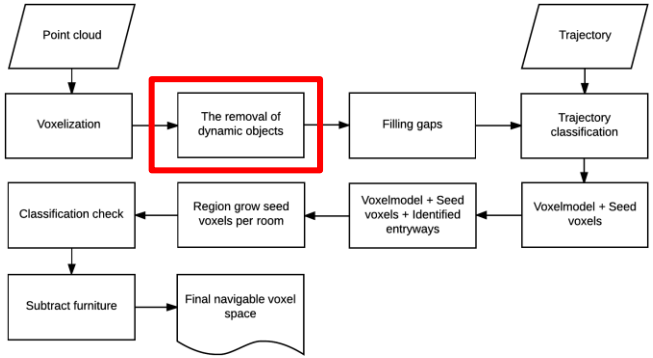
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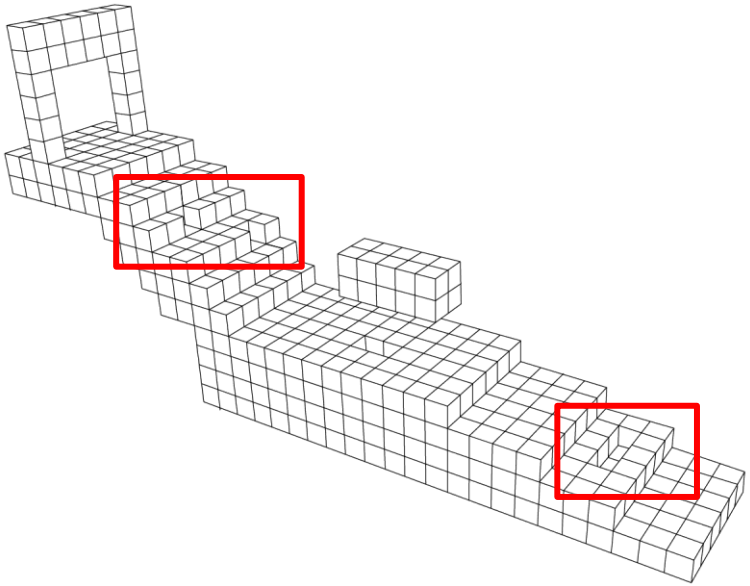
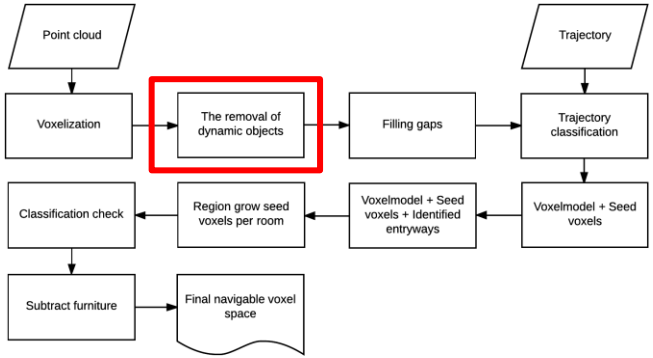
Voxelmodel + Seed voxels
Subtract furniture
Final navigable voxel space

Method




Point cloud
Trajectory
Voxelization
The removal of dynamic objects
Filling gaps
Trajectory classification
Classification check
Region grow seed voxels per room
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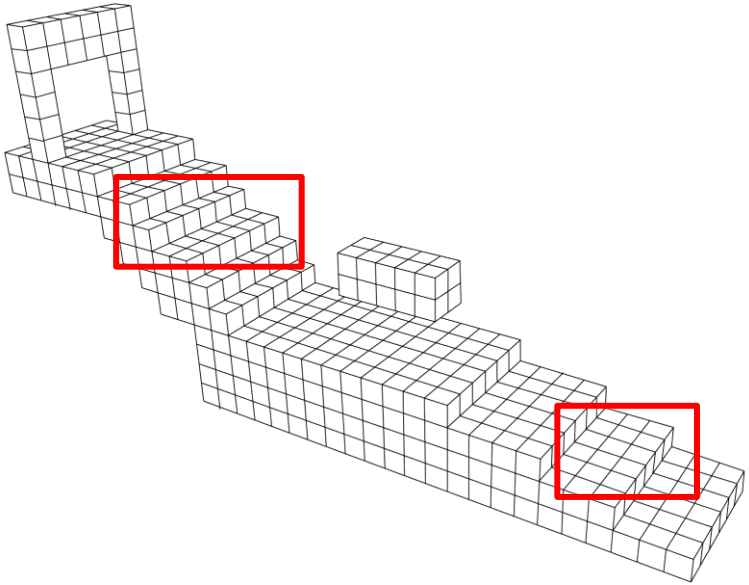

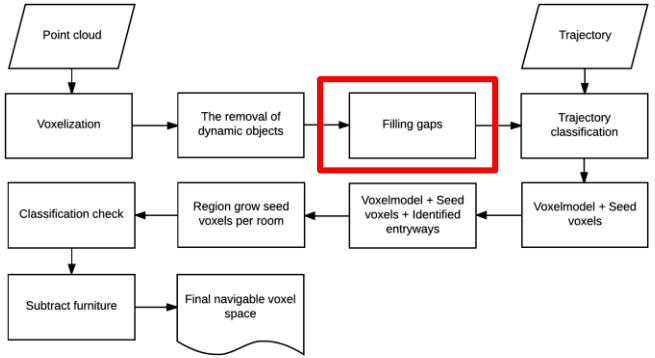
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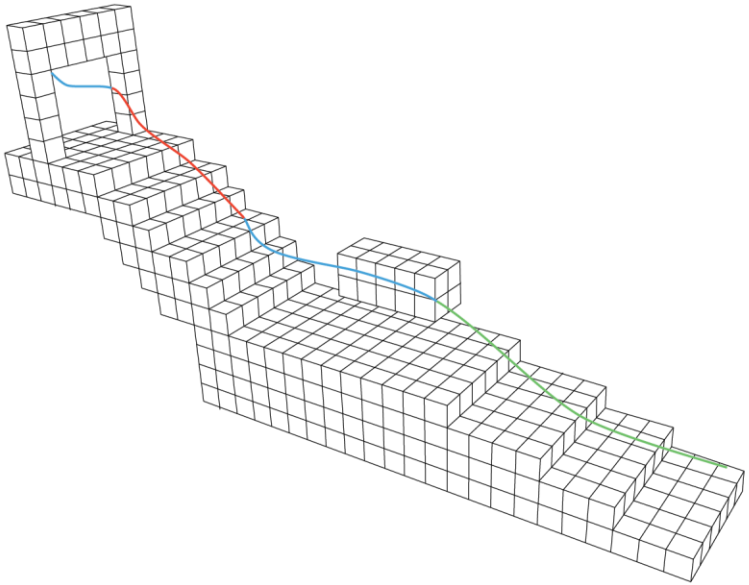

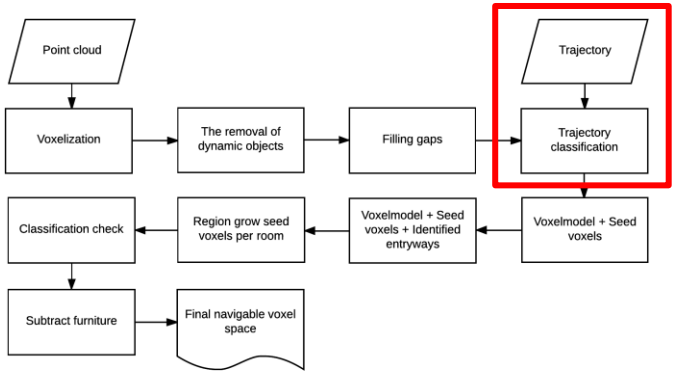
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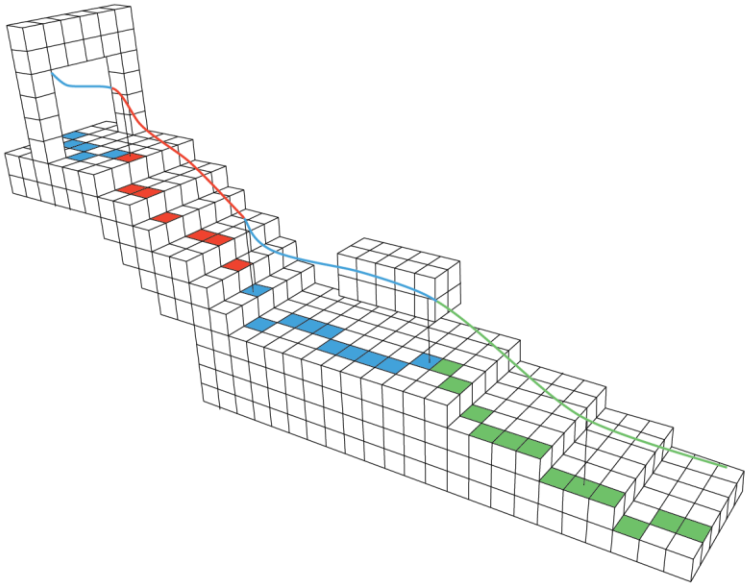

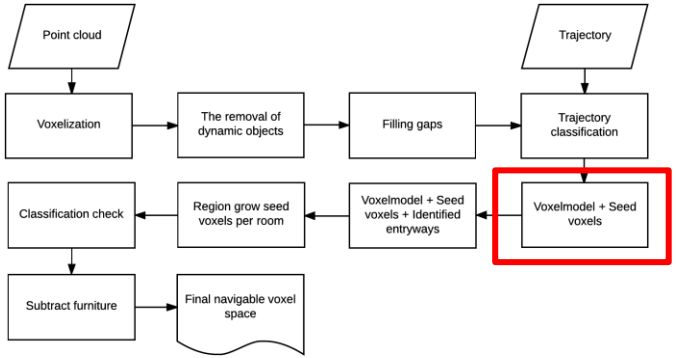
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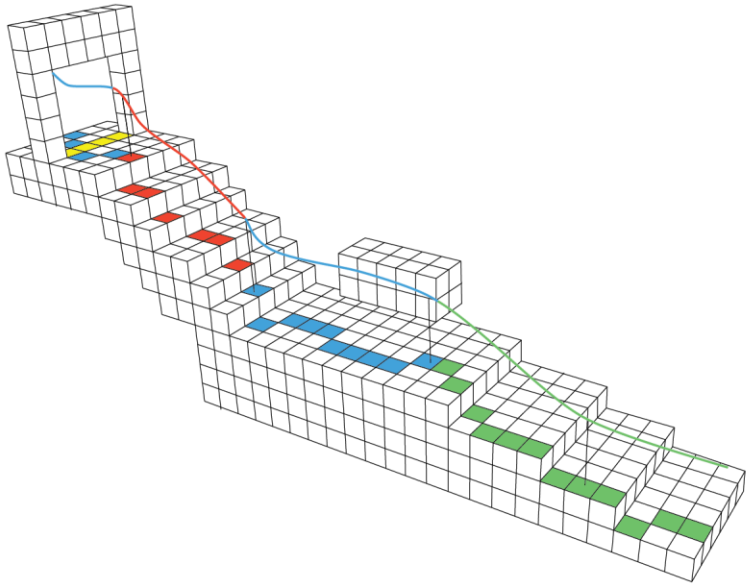

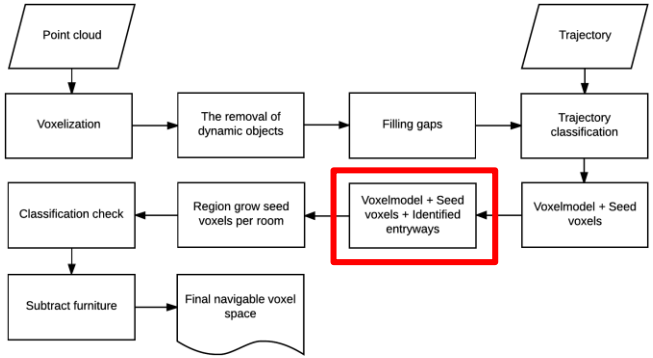
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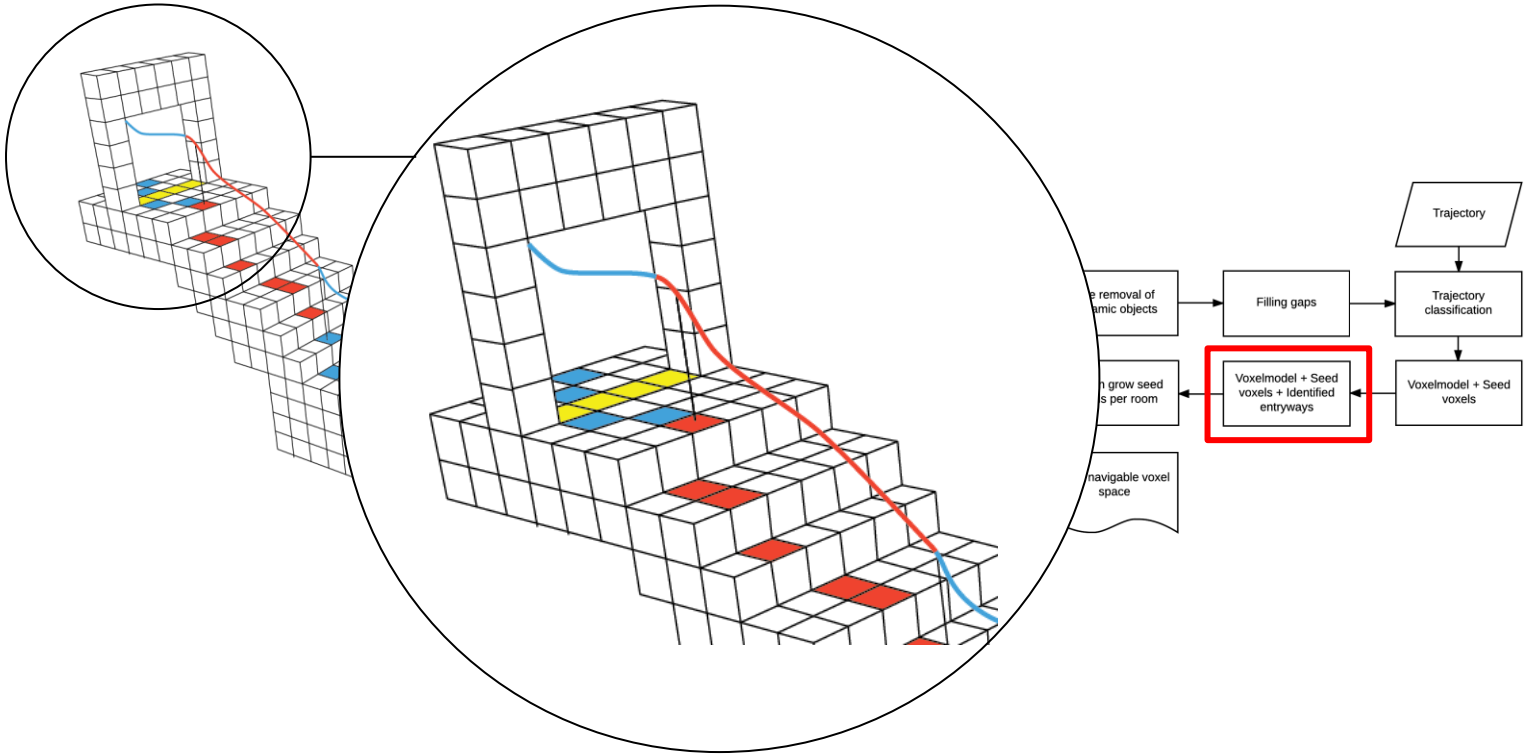
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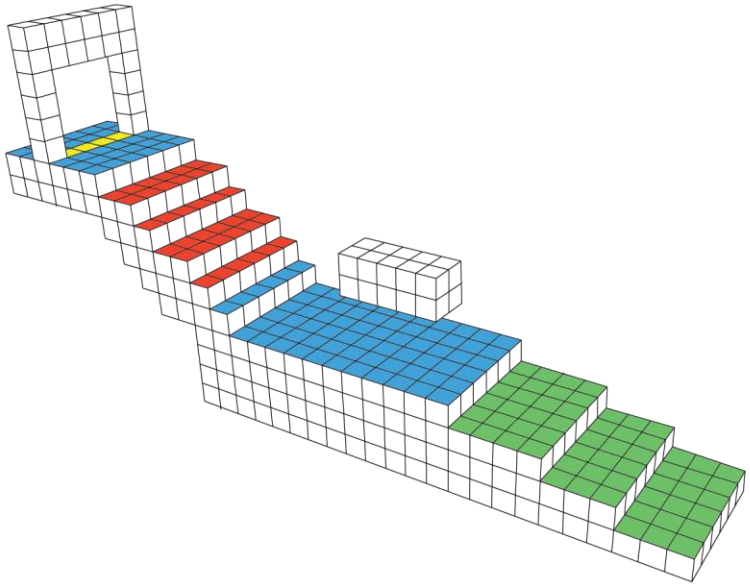
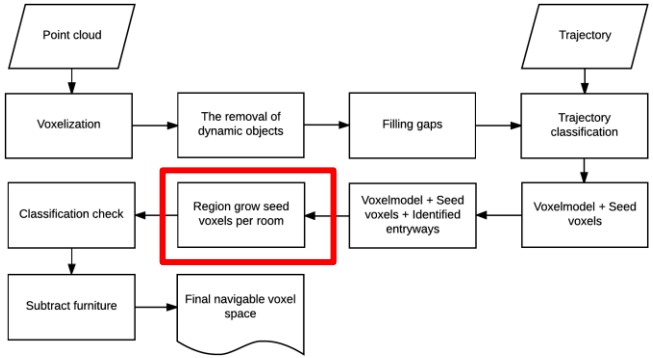
Trajectory classification
Filling gaps
Voxelmodel + Seed voxels
Voxelmodel + Seed voxels + Identified entryways
grow seed
s per room
navigable voxel space

Method

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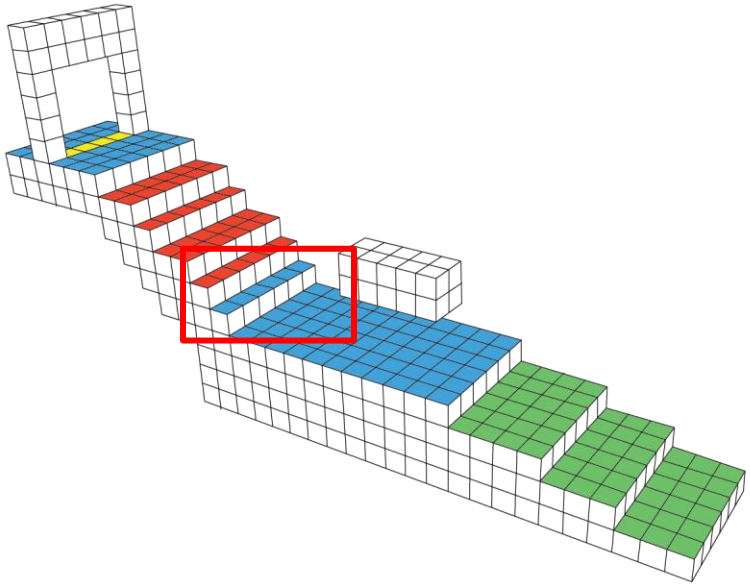

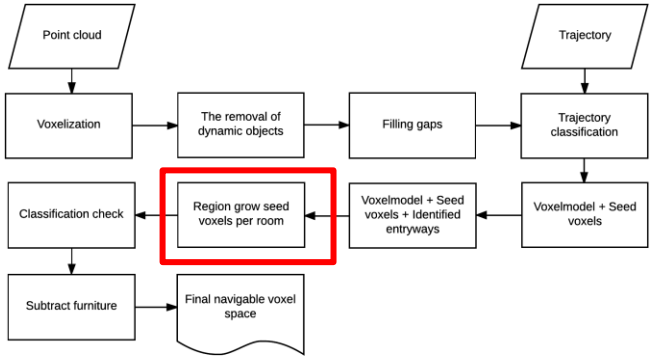
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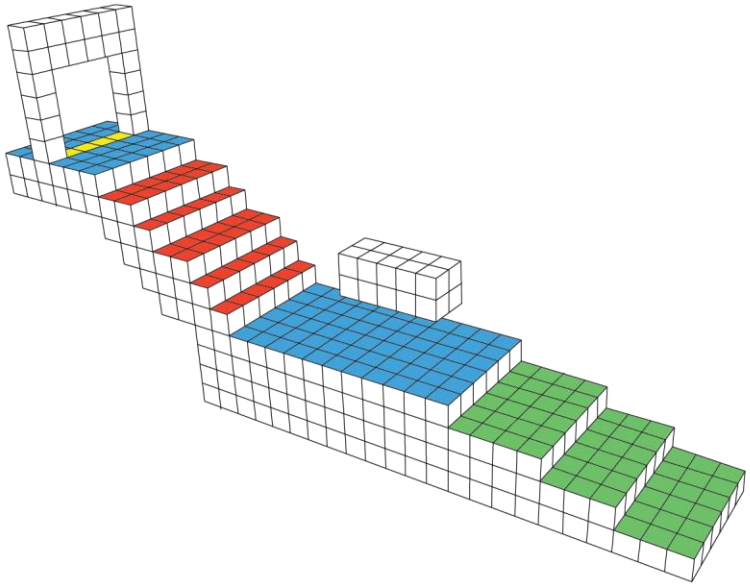

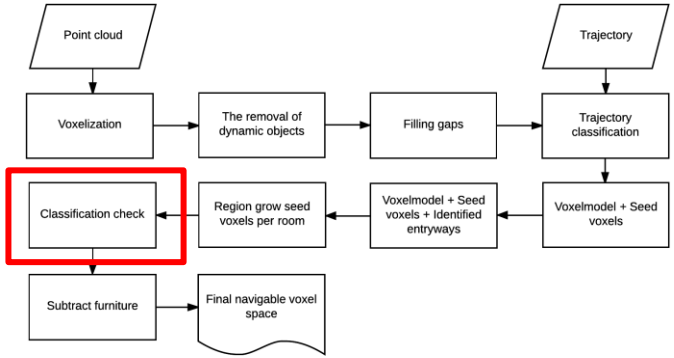
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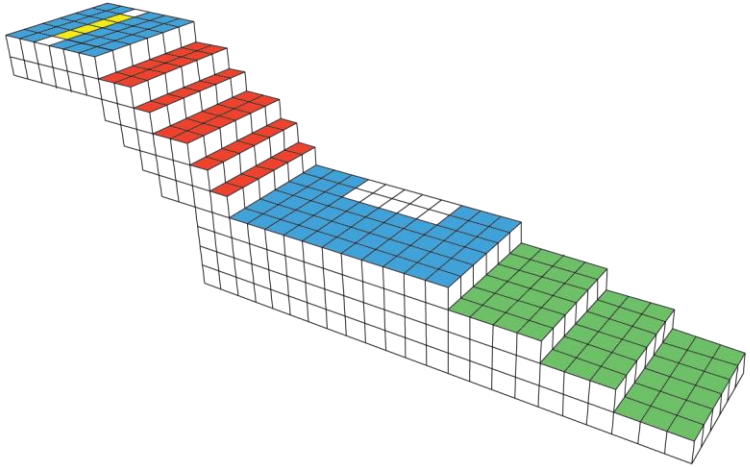

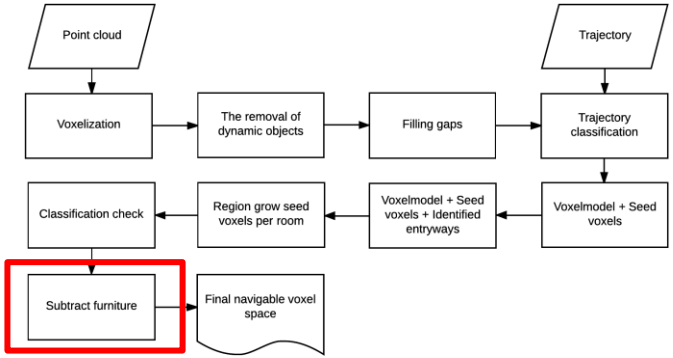
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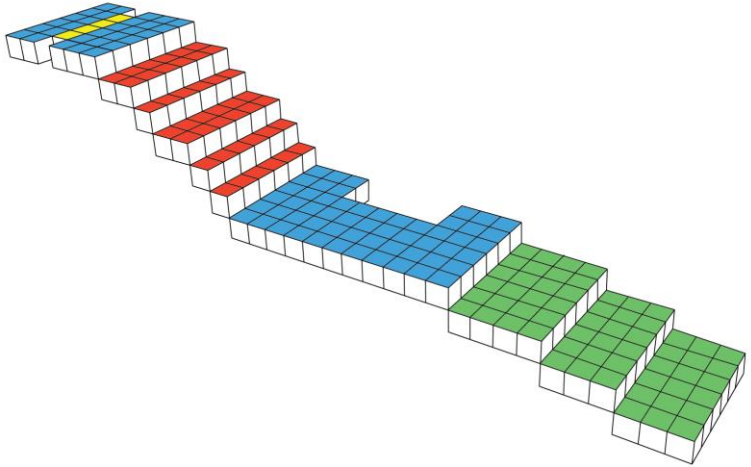

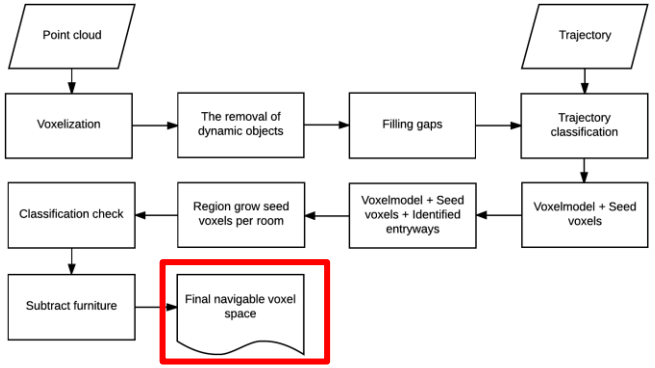
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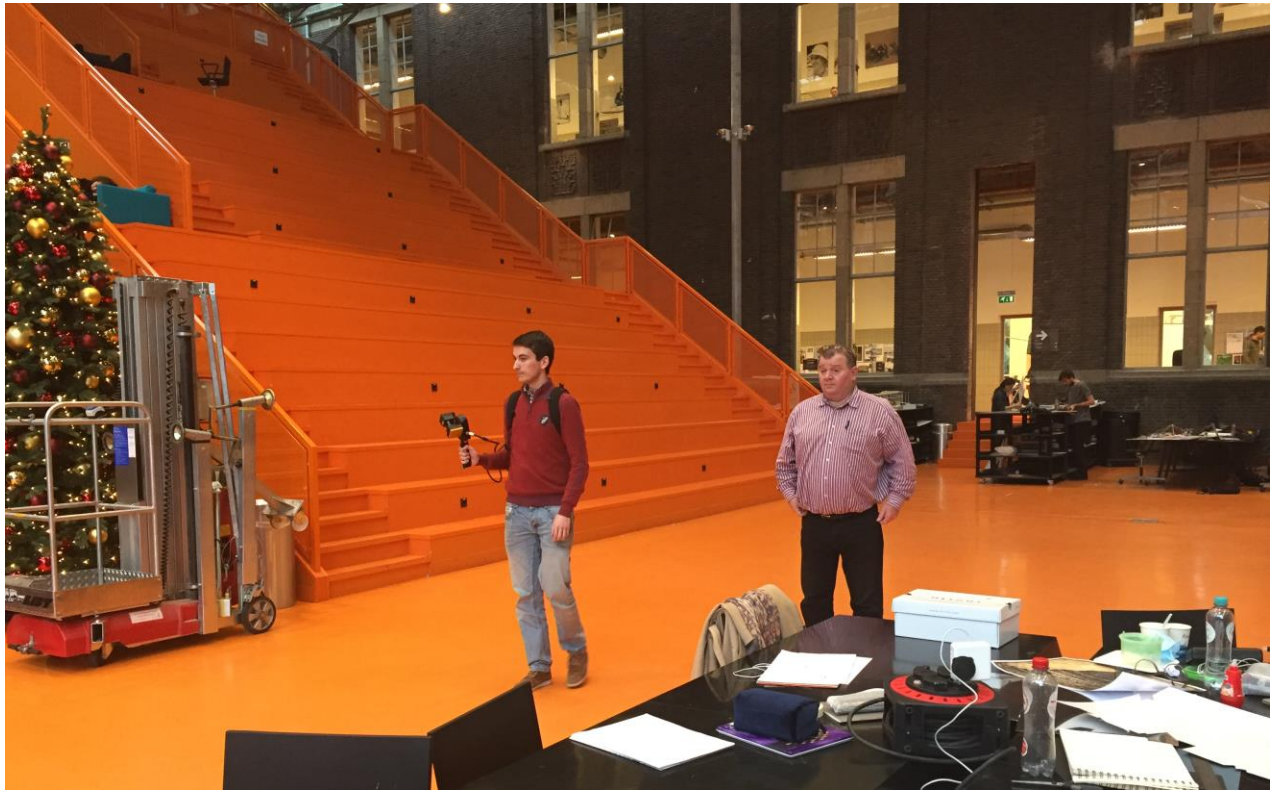
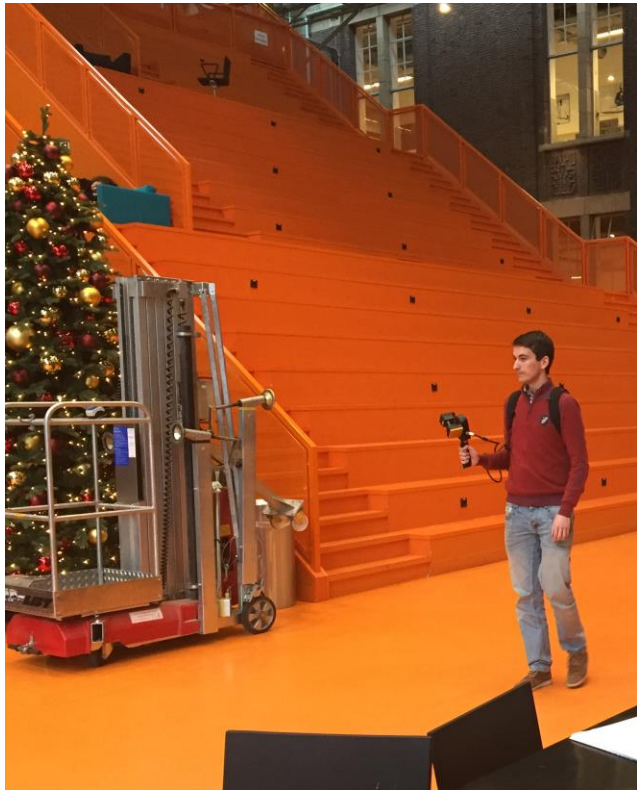
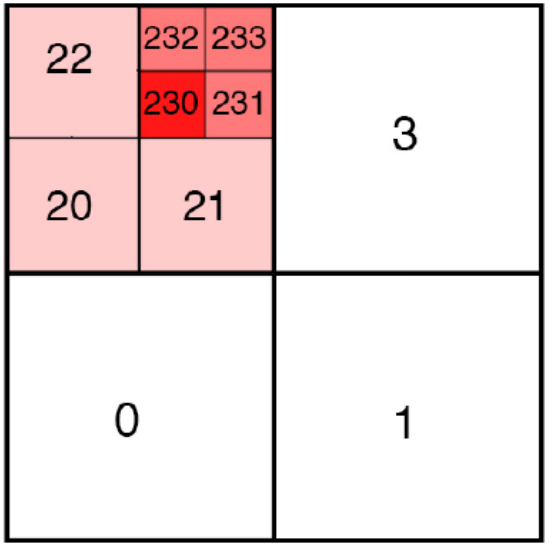
Data capture

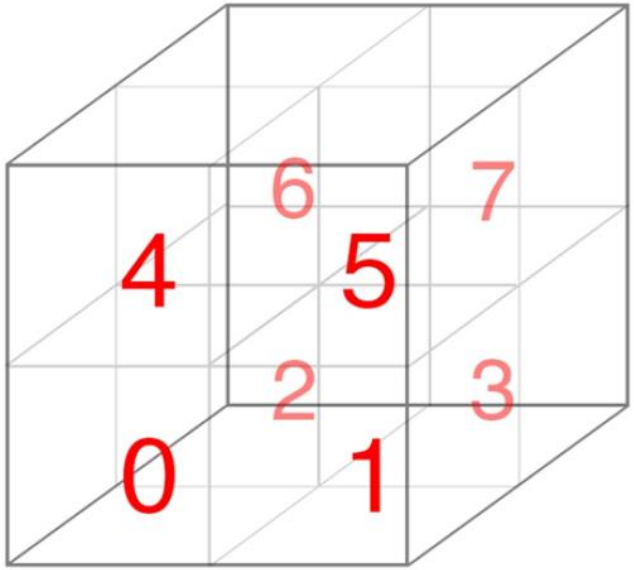


Data capture

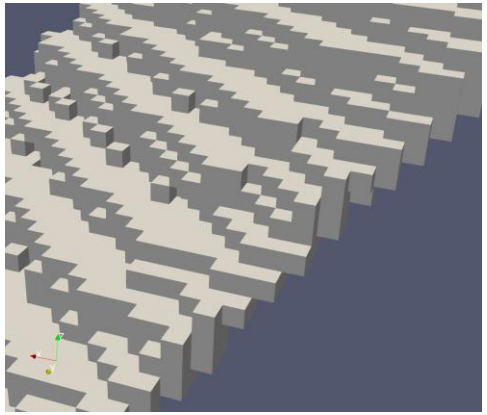


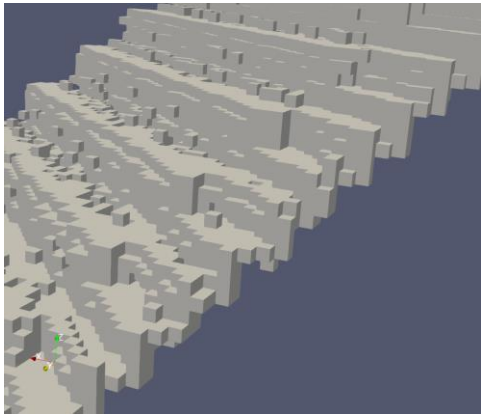
Voxelization: Octree structure





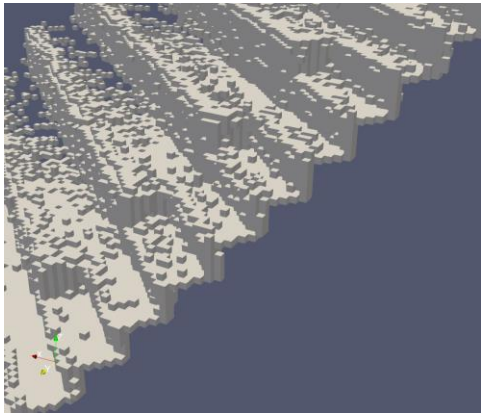
Voxel size:
14,6 cm

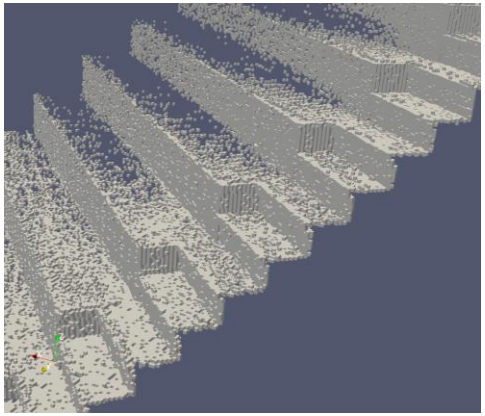




Voxel size:
7,3 cm

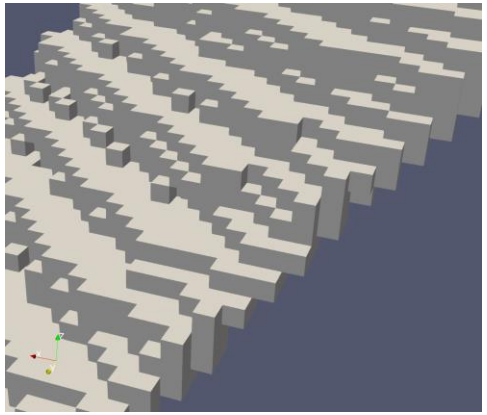
Voxel size:
3,6 cm

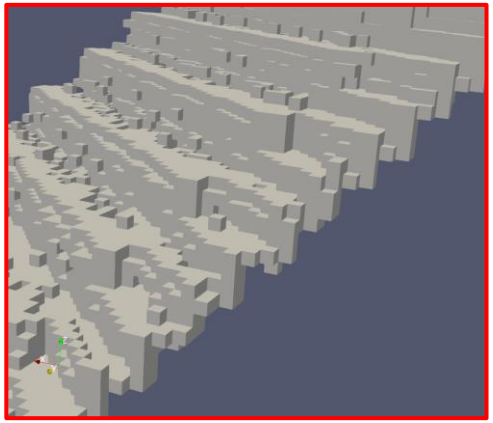




Voxel size:
1,8 cm

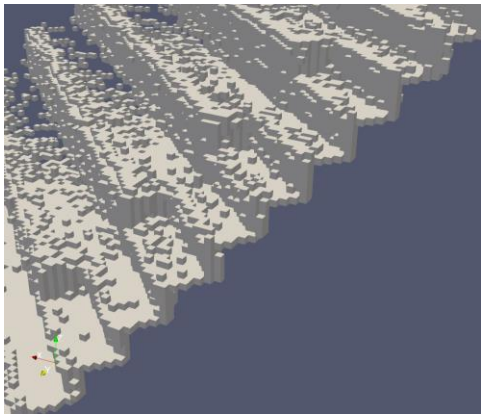
Voxel size:
14,6 cm

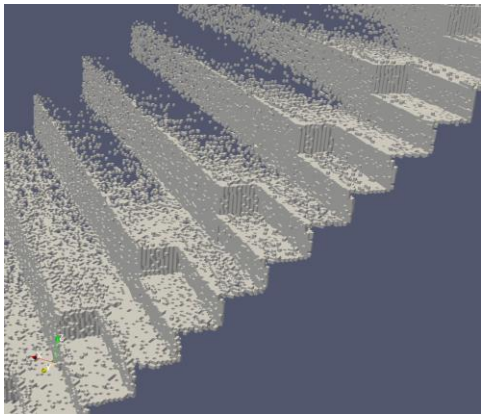




Voxel size:
7,3 cm

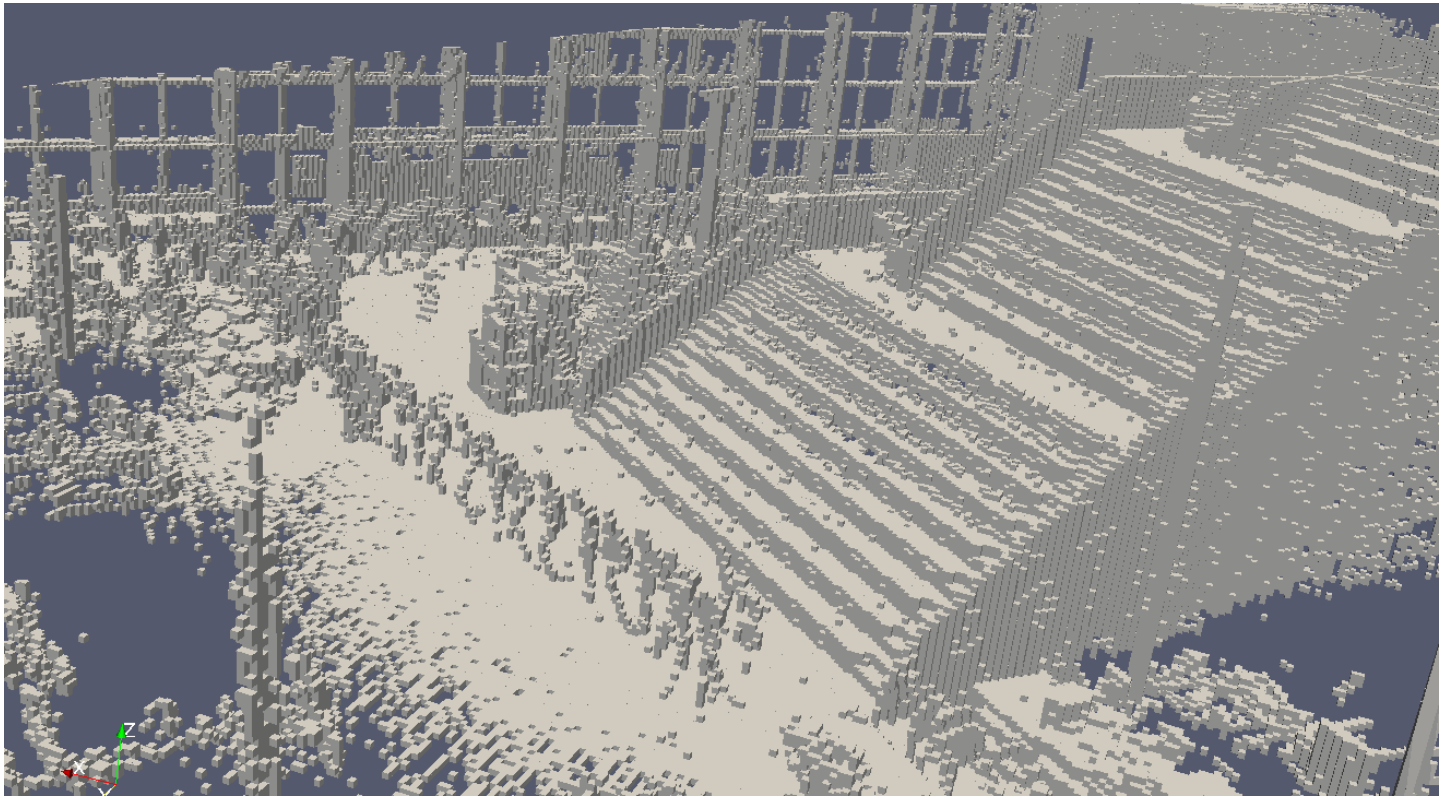
Voxel size:
3,6 cm





Voxel size:
1,8 cm

Voxelization



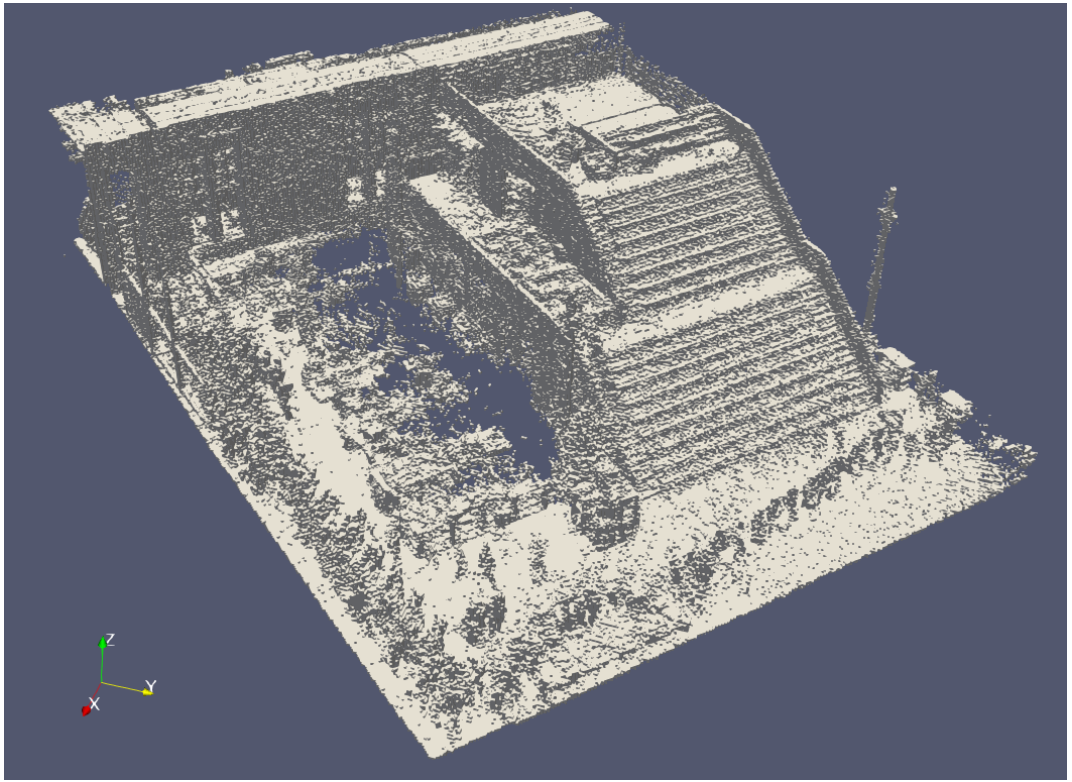
Remove dynamic objects

	Focus on dynamic objects	Scanning one time	Occusion no large impact	Detect dynamic objects one place	Beginning of process	No proble long drawn shadows
N-amount of voxels	−	+	+	+	+	+
Different time frames	+	−	−	−	+	+
Unique time stamps	+	+	+	−	+	+
Floor and voxels above	+	+	+	−	−	+
Count voxels above	+	+	+	+	−	−

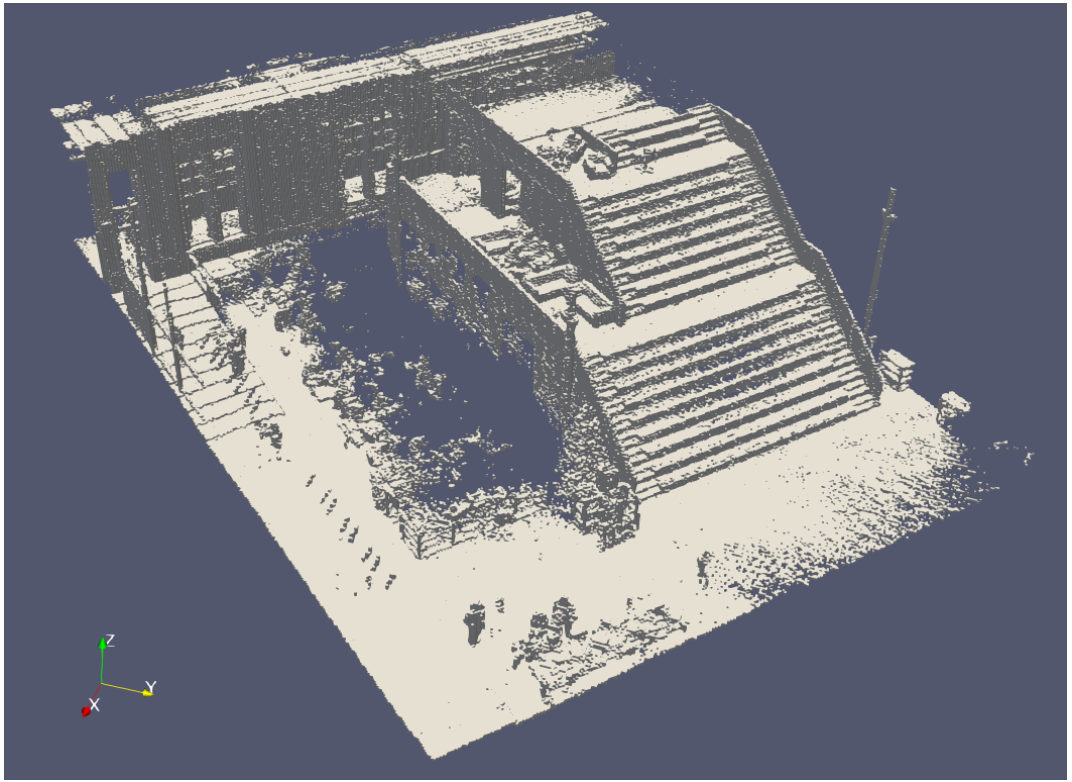
Remove dynamic objects

	Focus on dynamic objects	Scanning one time	Occusion no large impact	Detect dynamic objects one place	Beginning of process	No proble long drawn shadows
N-amount of voxels	−	+	+	+	+	+
Different time frames	+	−	−	−	+	+
Unique time stamps	+	+	+	−	+	+
Floor and voxels above	+	+	+	−	−	+
Count voxels above	+	+	+	+	−	−

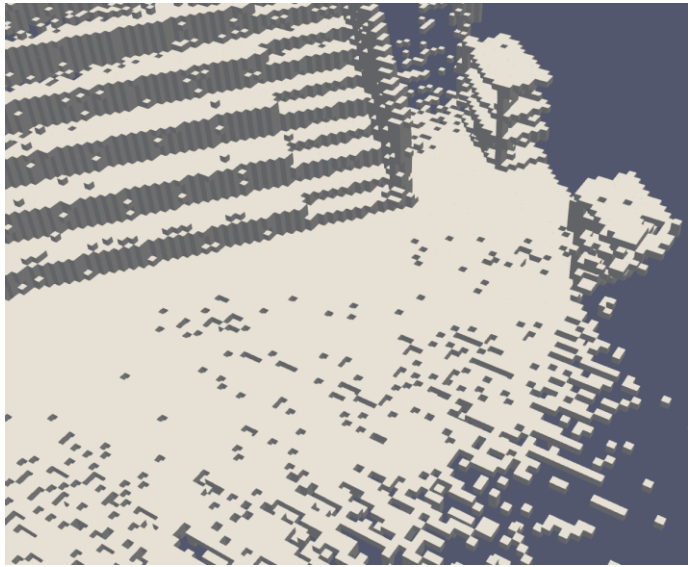
Remove dynamic objects



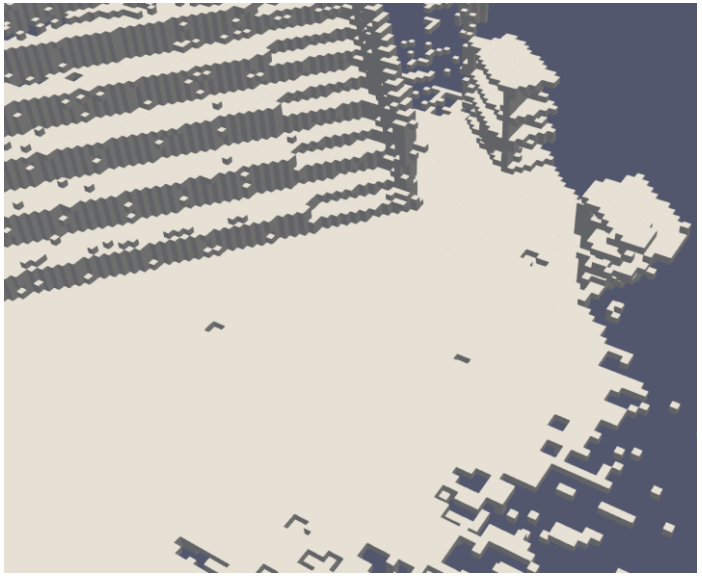
Remove dynamic objects



Filling gaps

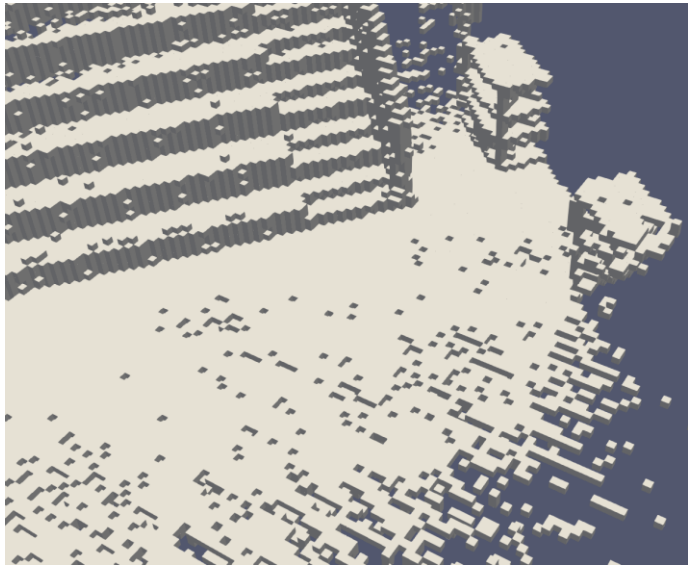


Original voxel model

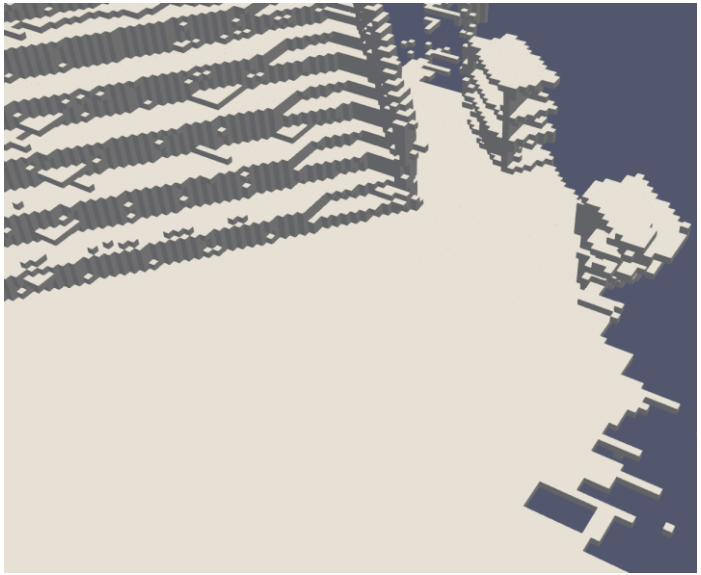


Filled if distance = 1

Filling gaps



Original voxel model

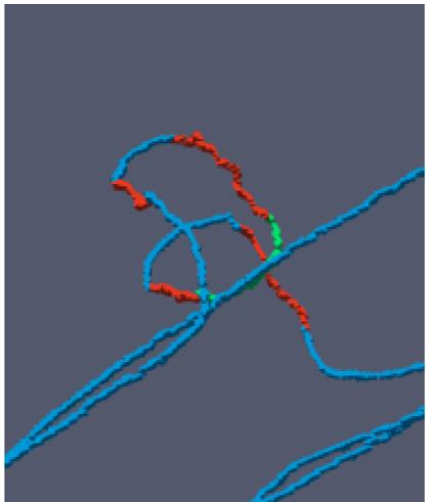


Filled if distance = 5

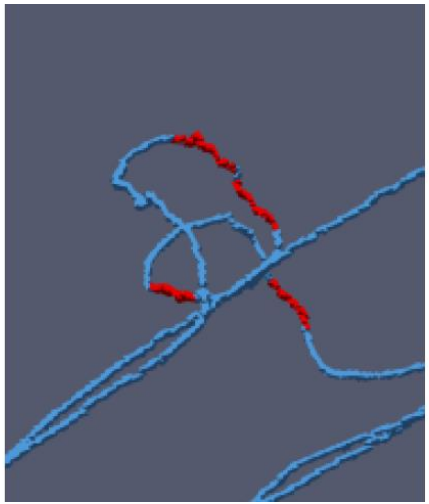
Trajectory classification

Testing Set	Slope Minimum angle in degree	Maximum angle in degree	connected elements	Stair Minimum angle in degree	Maximum angle in degree	connected elements
1	2.3	18.4	2	7.1a	90	4
2	2.3	11.3	2	7.1a	45	4
3	3.8	18.4	2	14	90	4

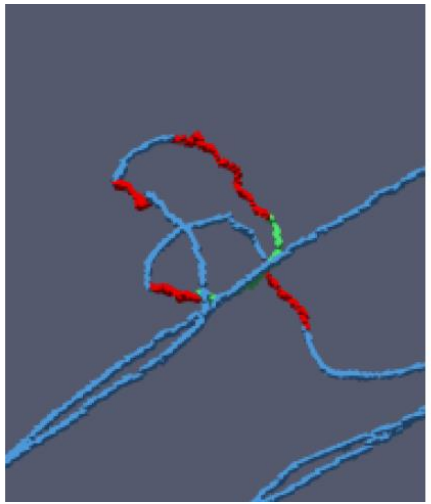
Trajectory classification



Testing set 1

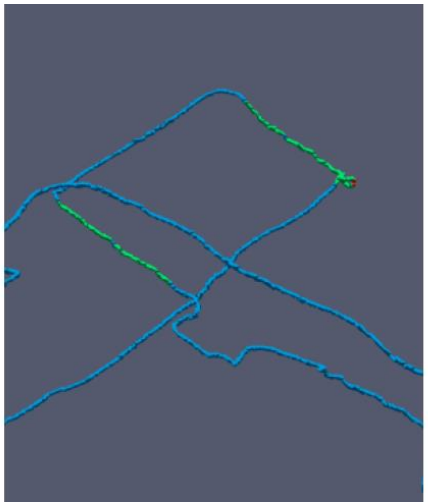


Testing set 2

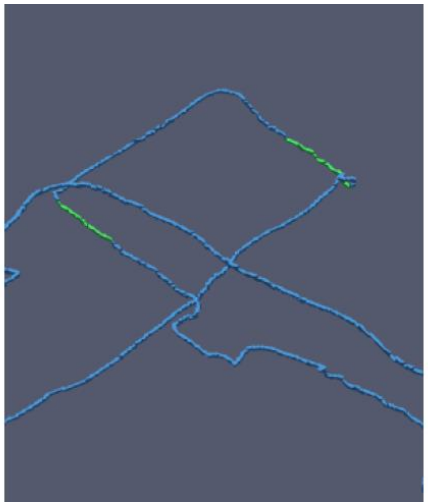


Testing set 3

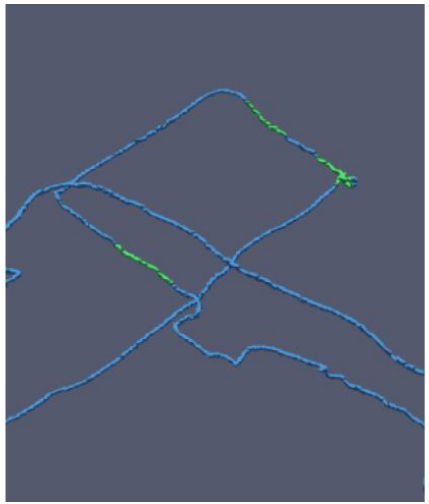
Trajectory classification



Testing set 1

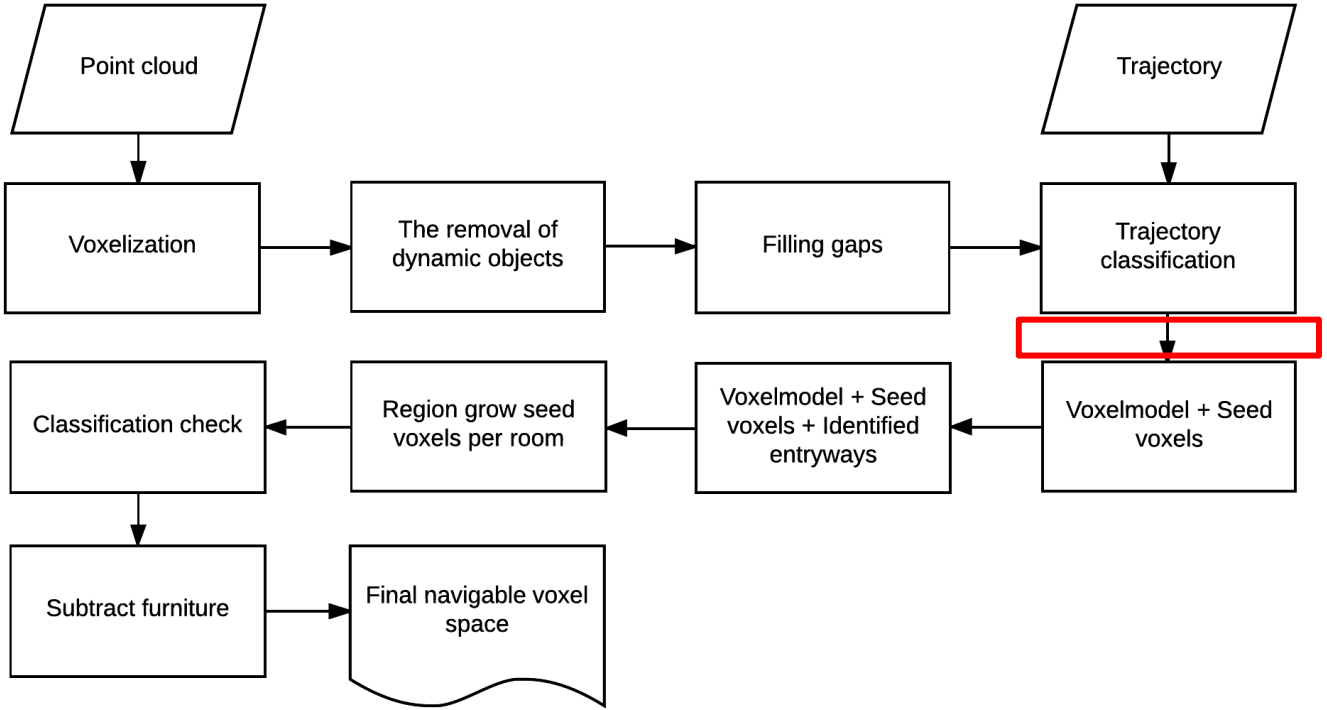


Testing set 2



Testing set 3

Method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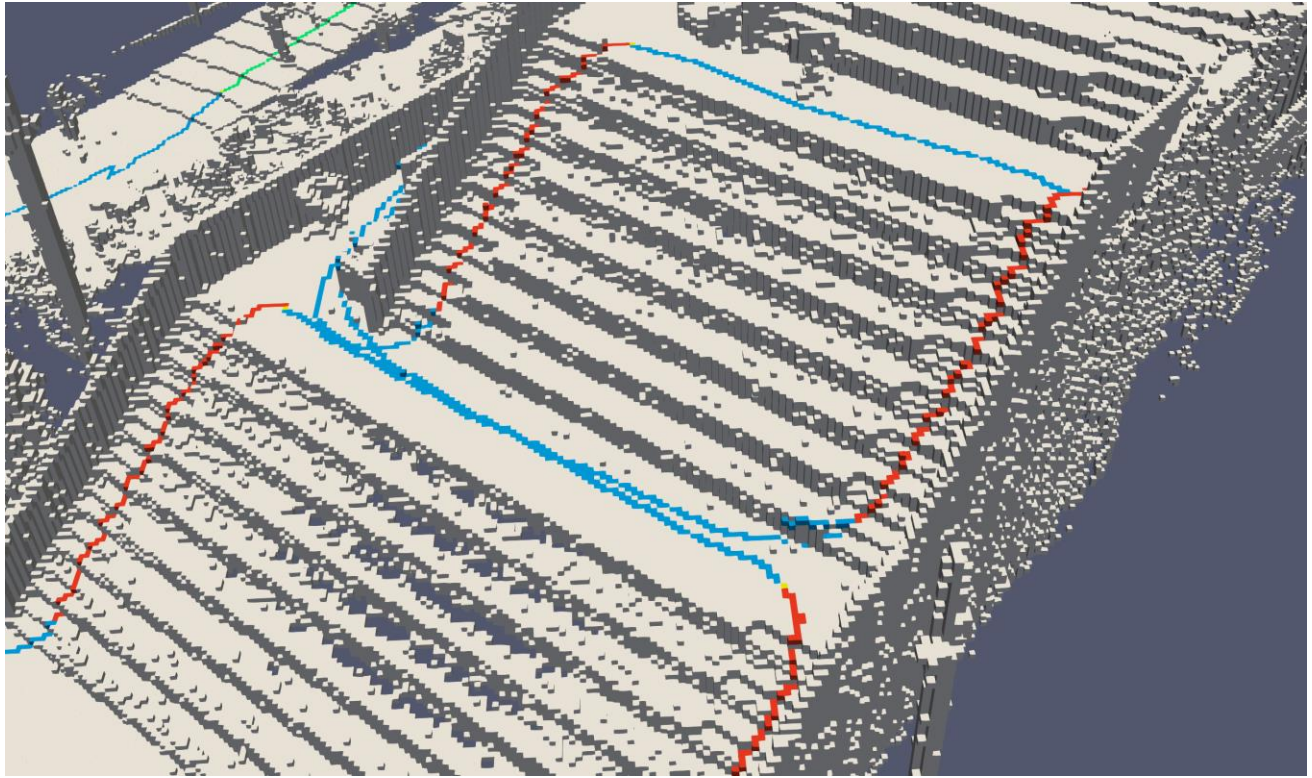
Voxelmodel + Seed voxels
Subtract furniture
Final navigable voxel space

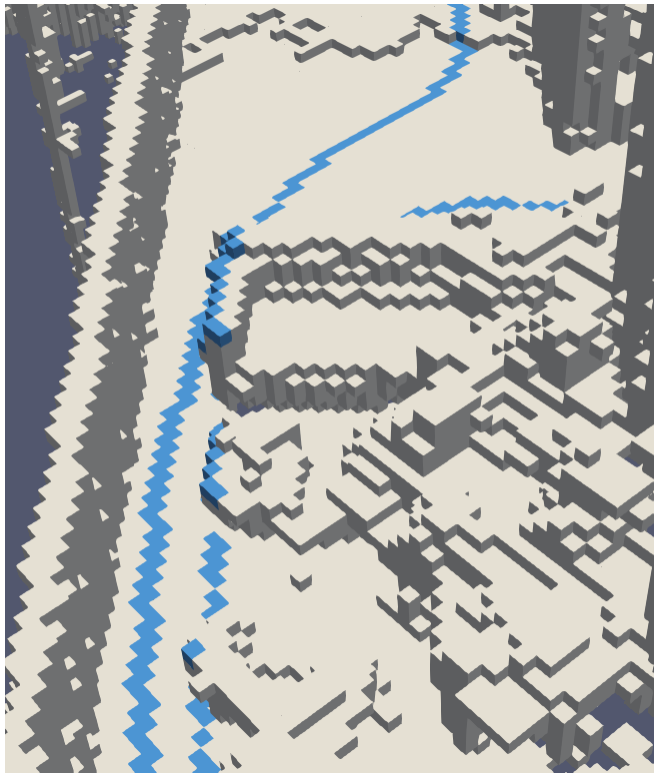
Voxel model + seed voxels

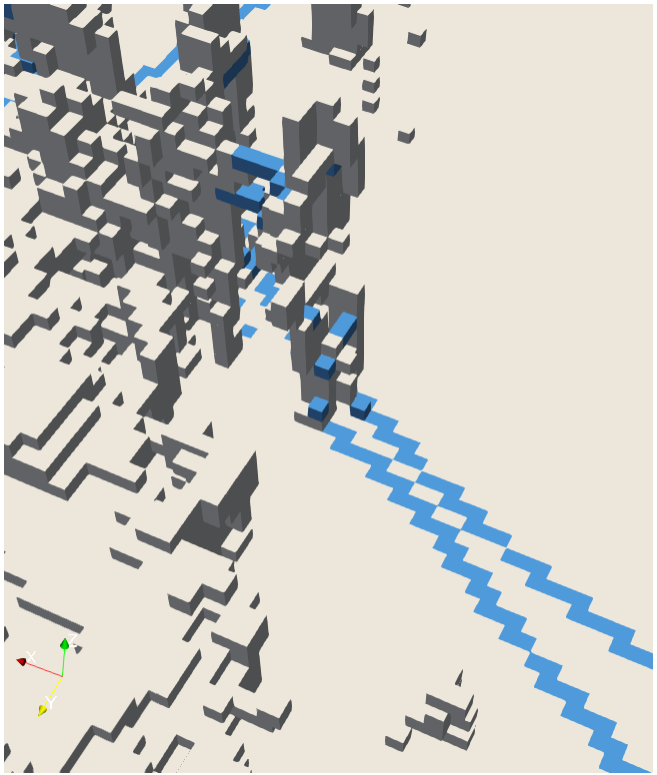


CGI

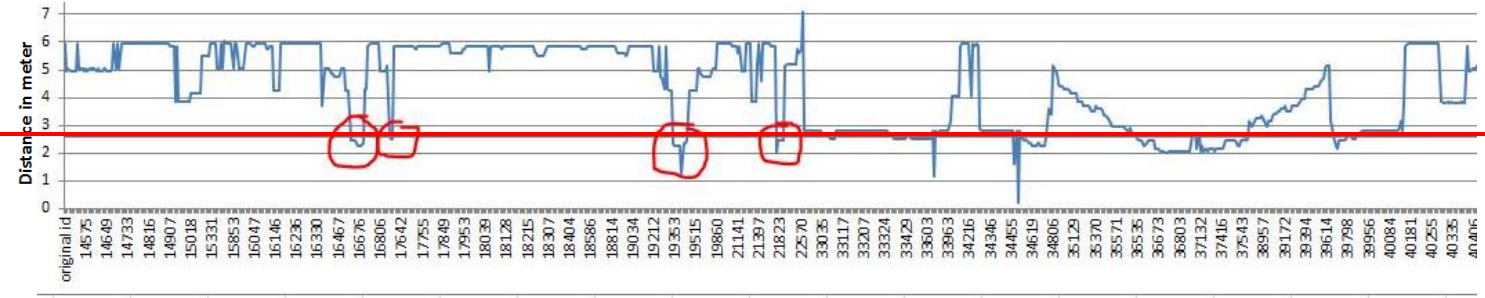
TUDelft

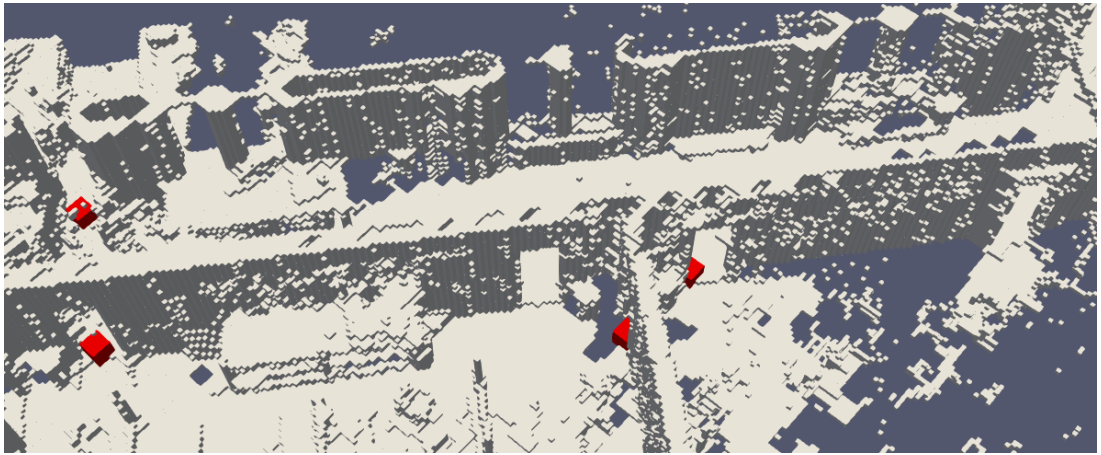
Voxel model + seed voxels



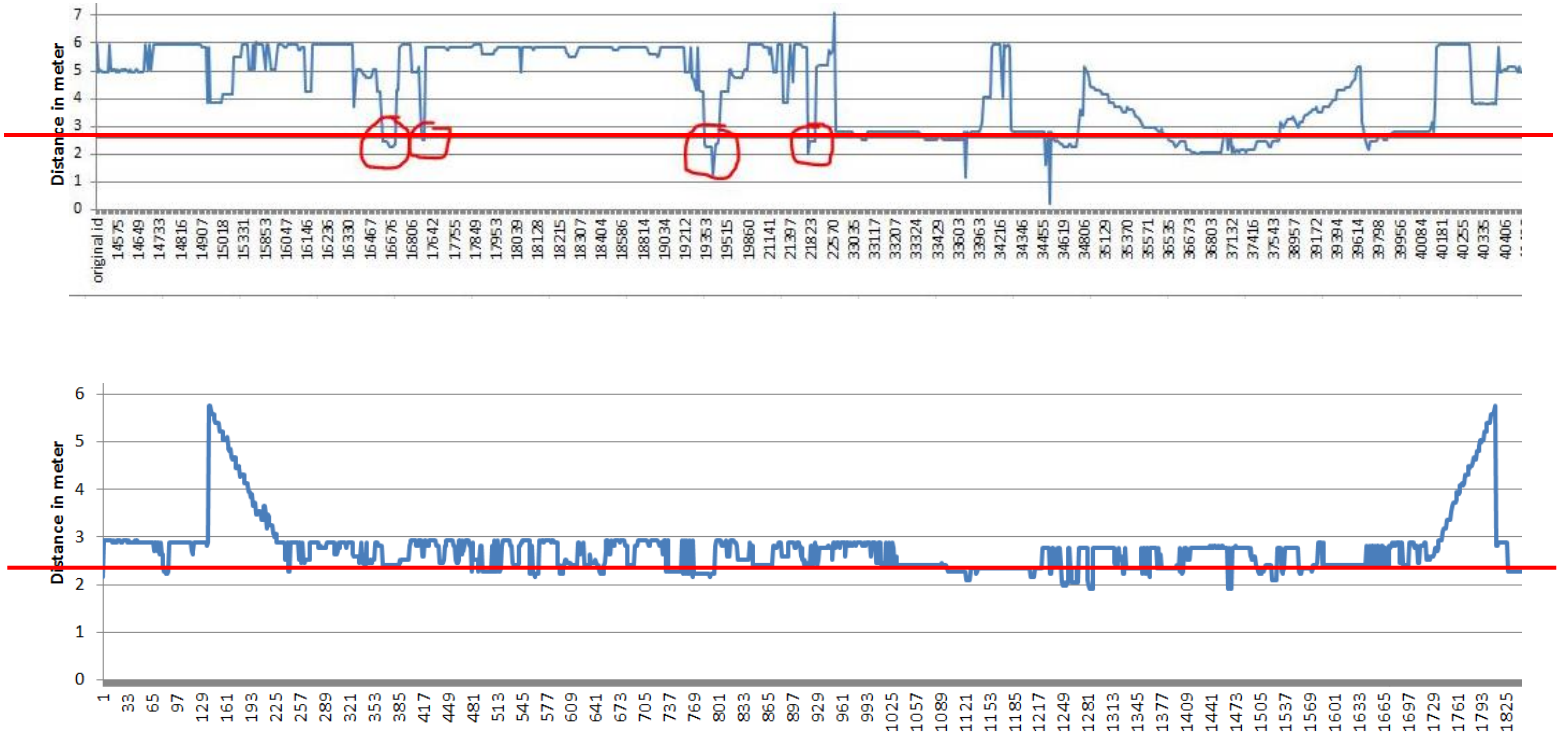


Voxel model + entryways





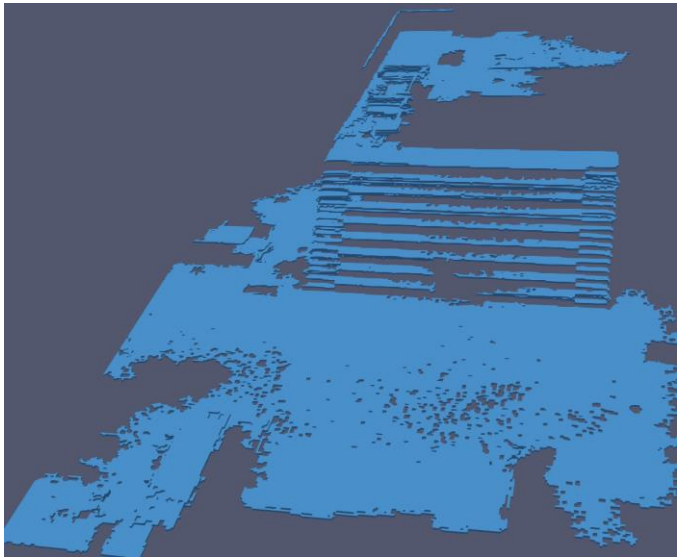
Voxel model + entryways



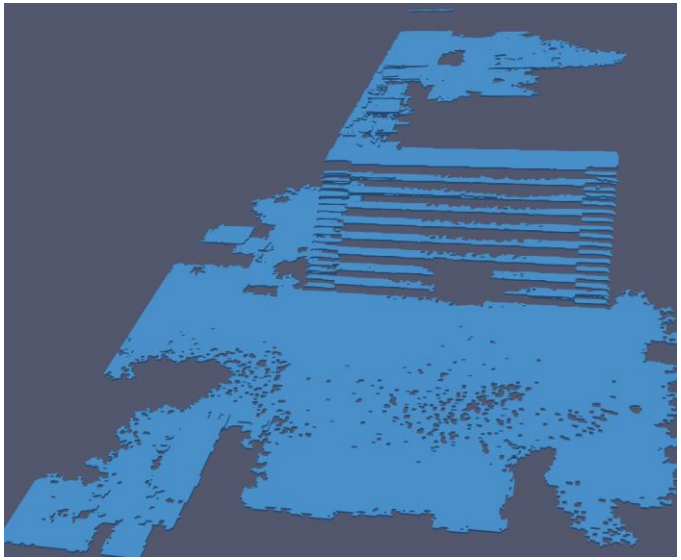
Region growing

- Find neighbors on the same level
- Two termination criteria:
  - Two voxels directly above
  - Entryway voxels

Region growing: two methods

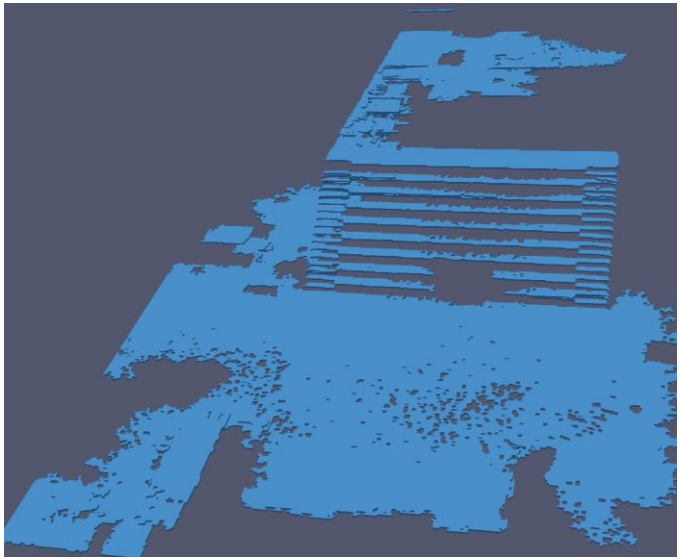


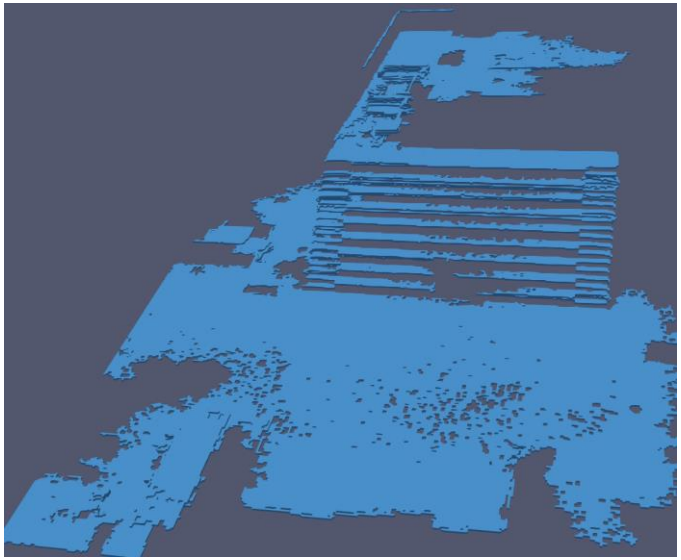
Ordered checking



DBSCAN

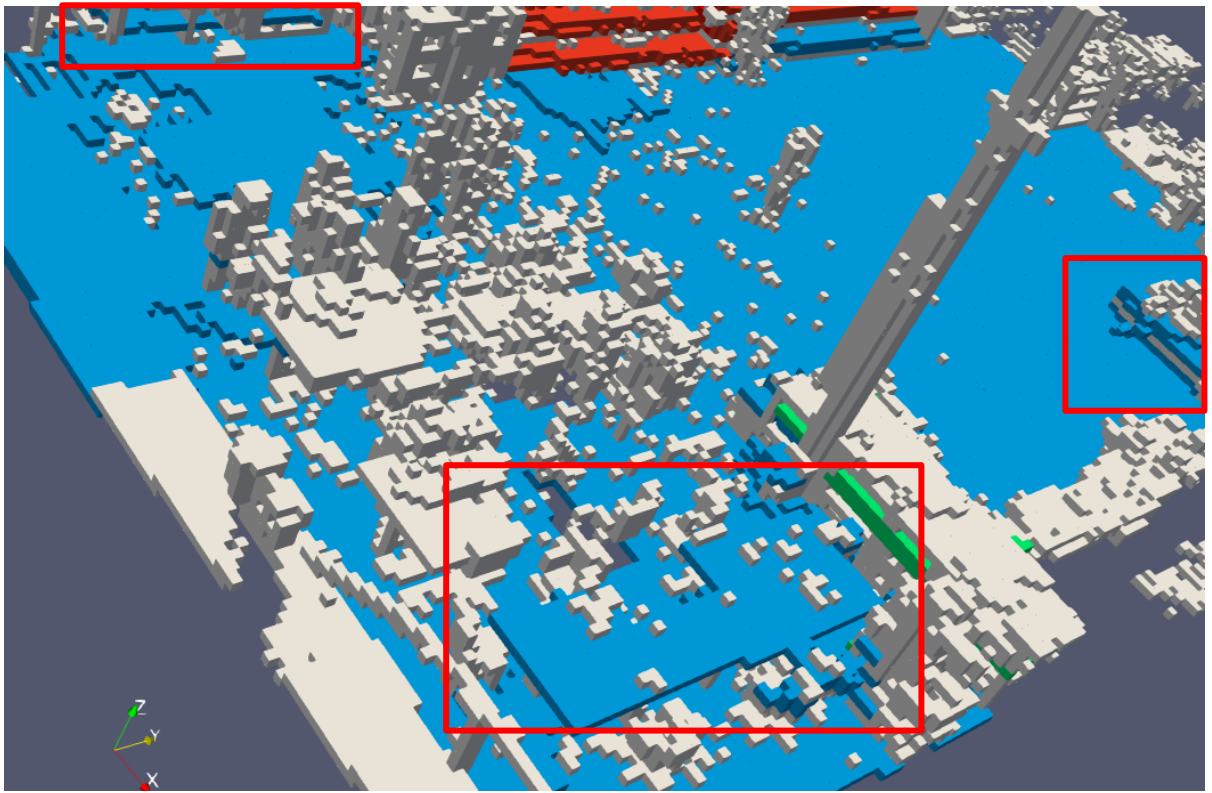
Region growing: two methods



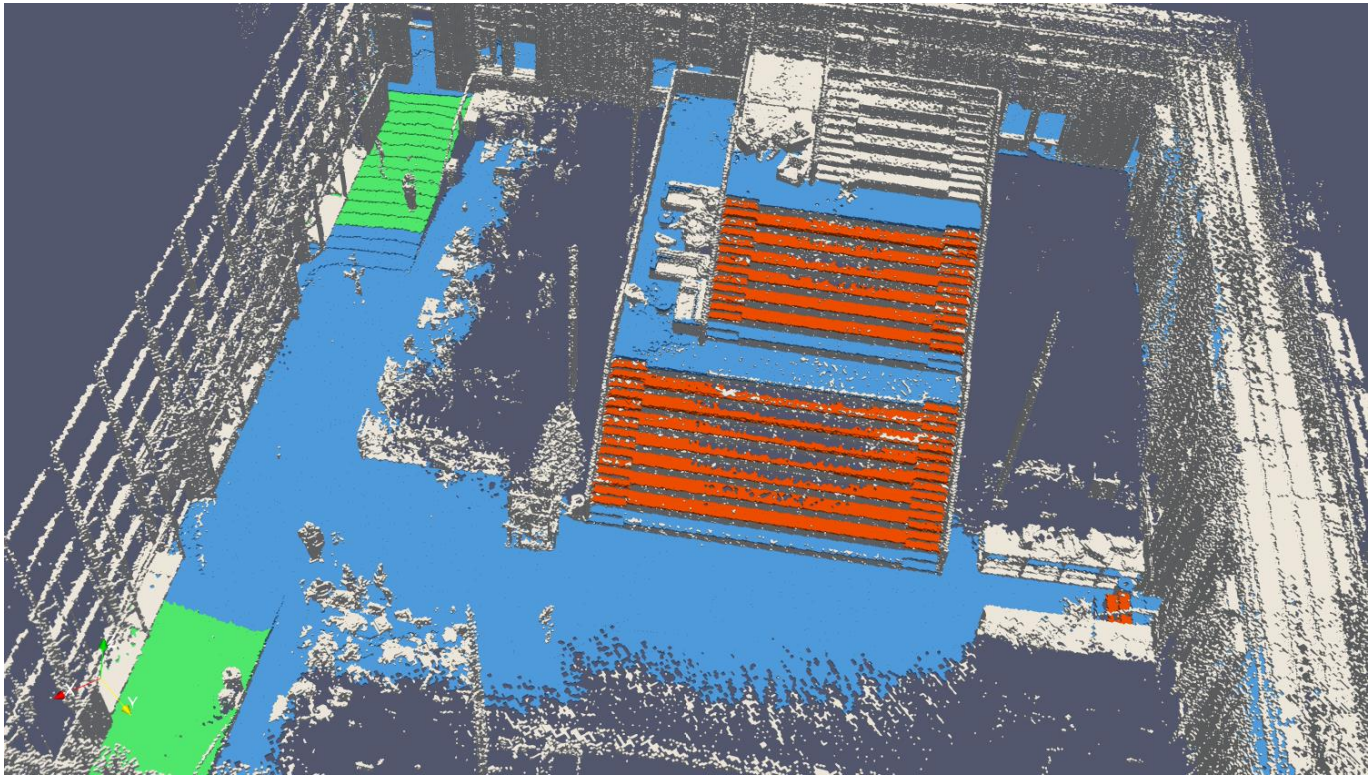


Region growing type	Processing time in minutes	Number of voxels	Largest region in voxels
ClusterDBSCAN eps = 1.5	17	84540	48320
Ordered checking	169	90292	48568

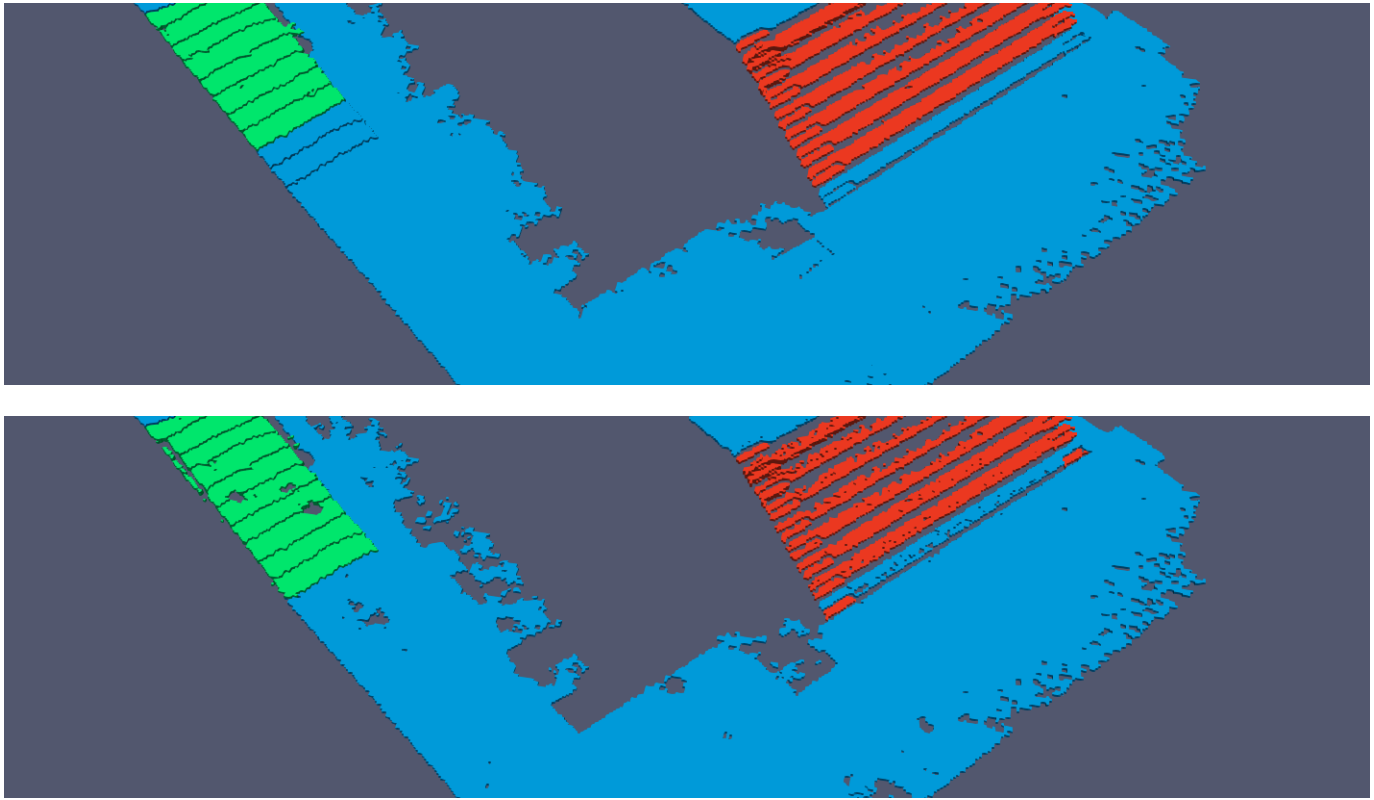
Region growing: furniture



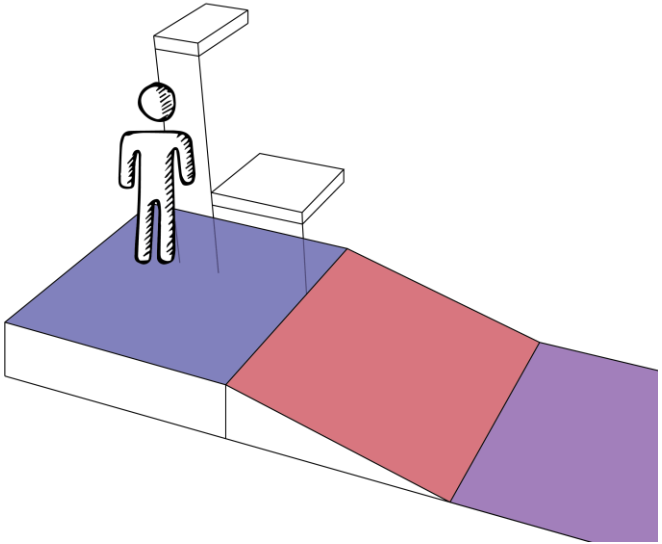
Classification check

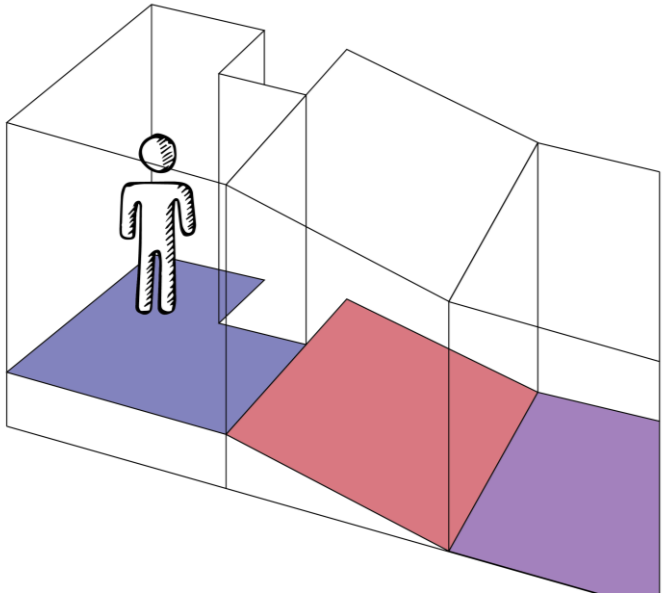


Classification check

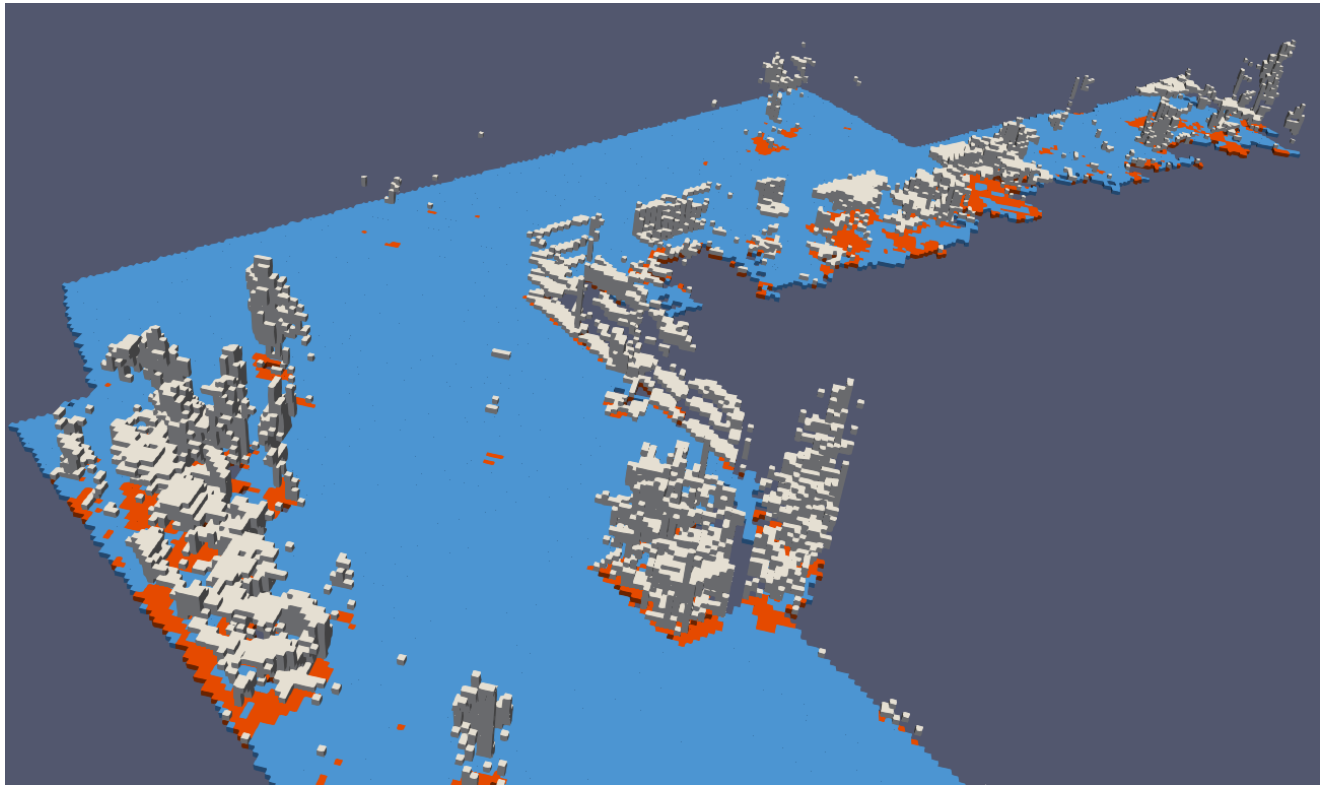


Subtract furniture: actor height





Subtract furniture



Results: representation

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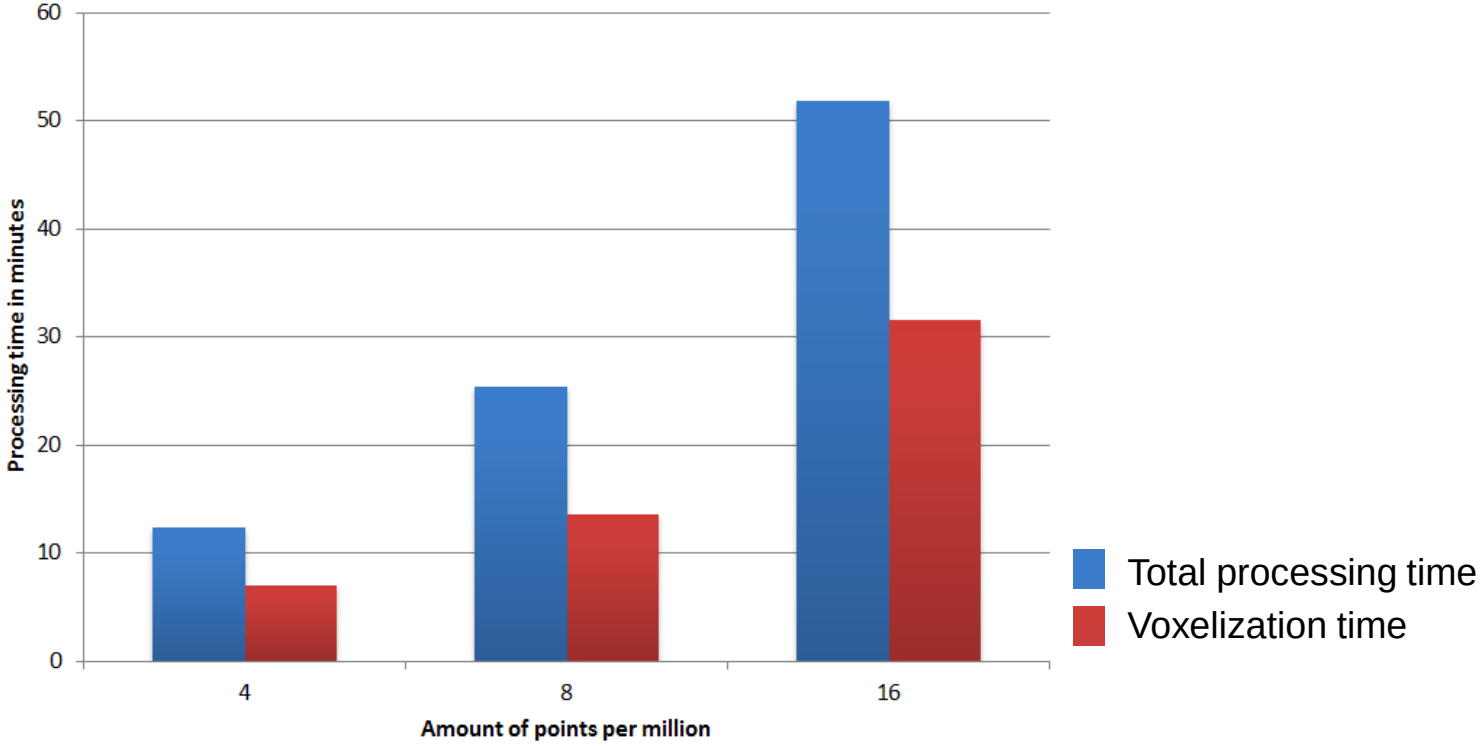
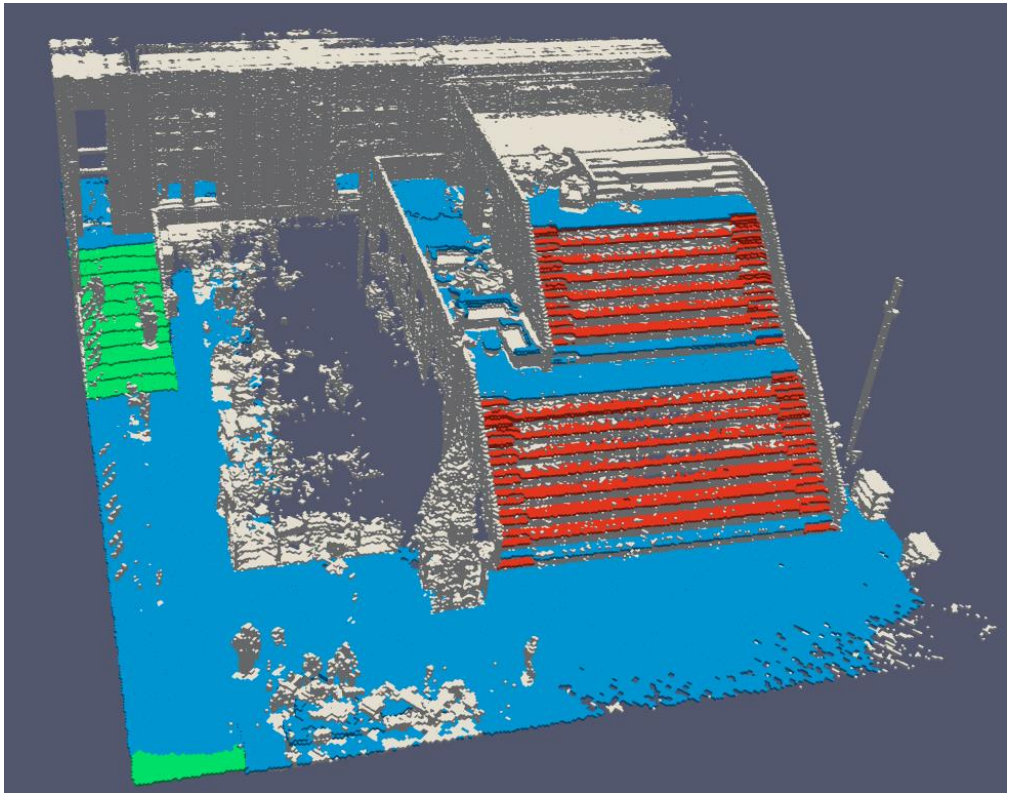
Results: representation

Checking type	Halway in m^2	First floor Orange rock in m^2
CAD model	74.0	68.0
7.3 cm voxel model	67.7	61.3
3.65 cm voxel model	67.5	61.9
Difference between CAD and 7.3 cm	-8.5 %	-9.9 %
Difference between CAD and 3.7 cm	-8.8 %	-9.0 %

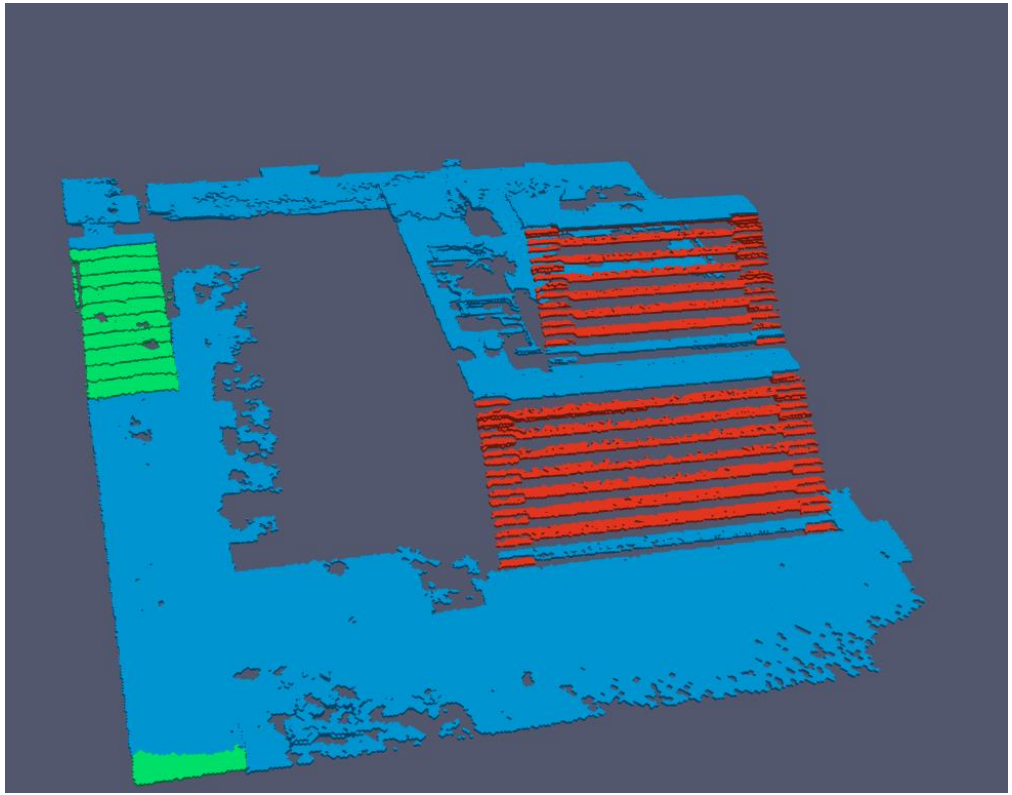
Results: processing time



Results: navigable space



Results: navigable space



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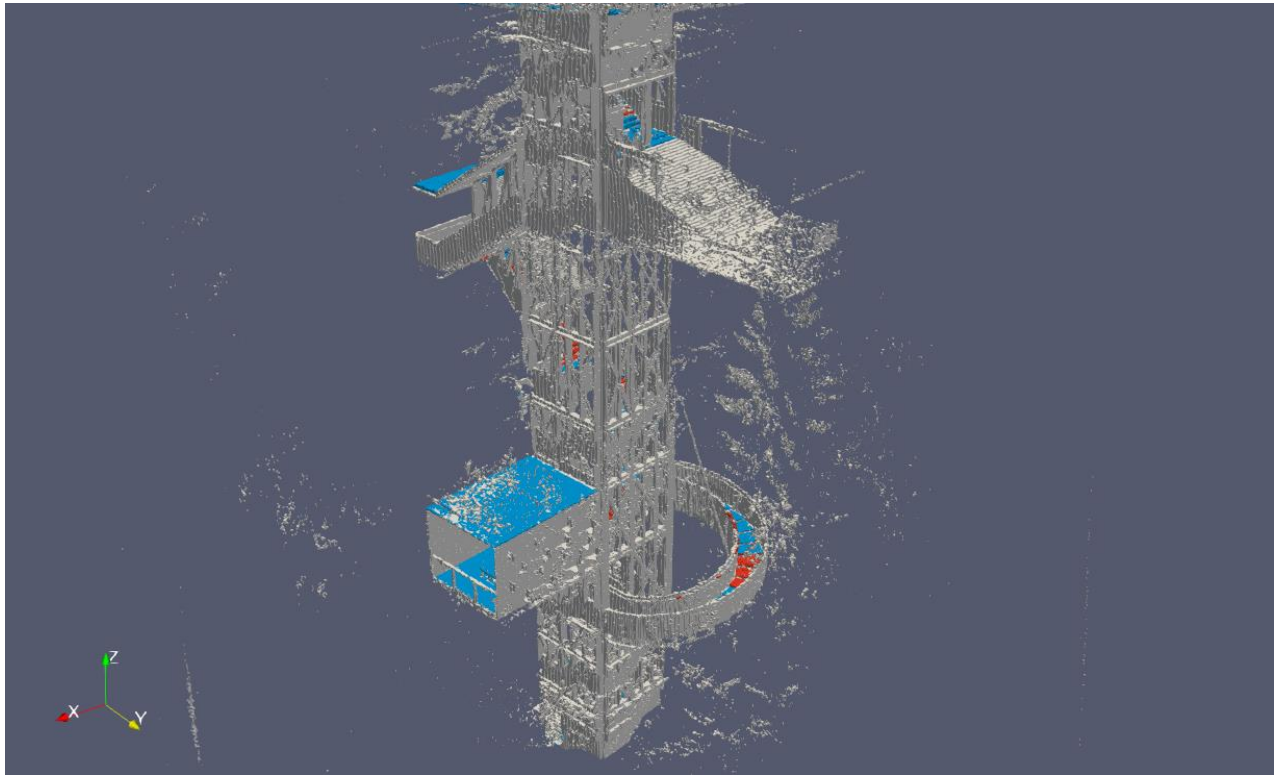
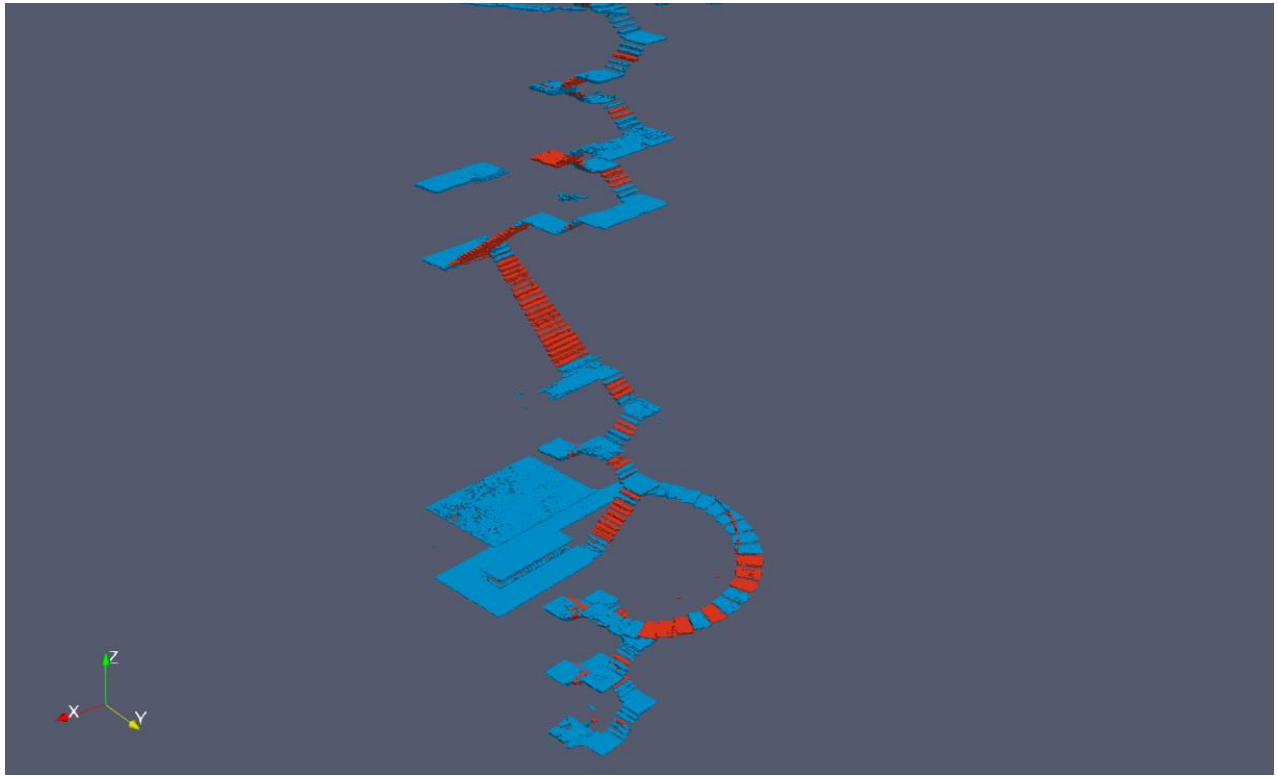
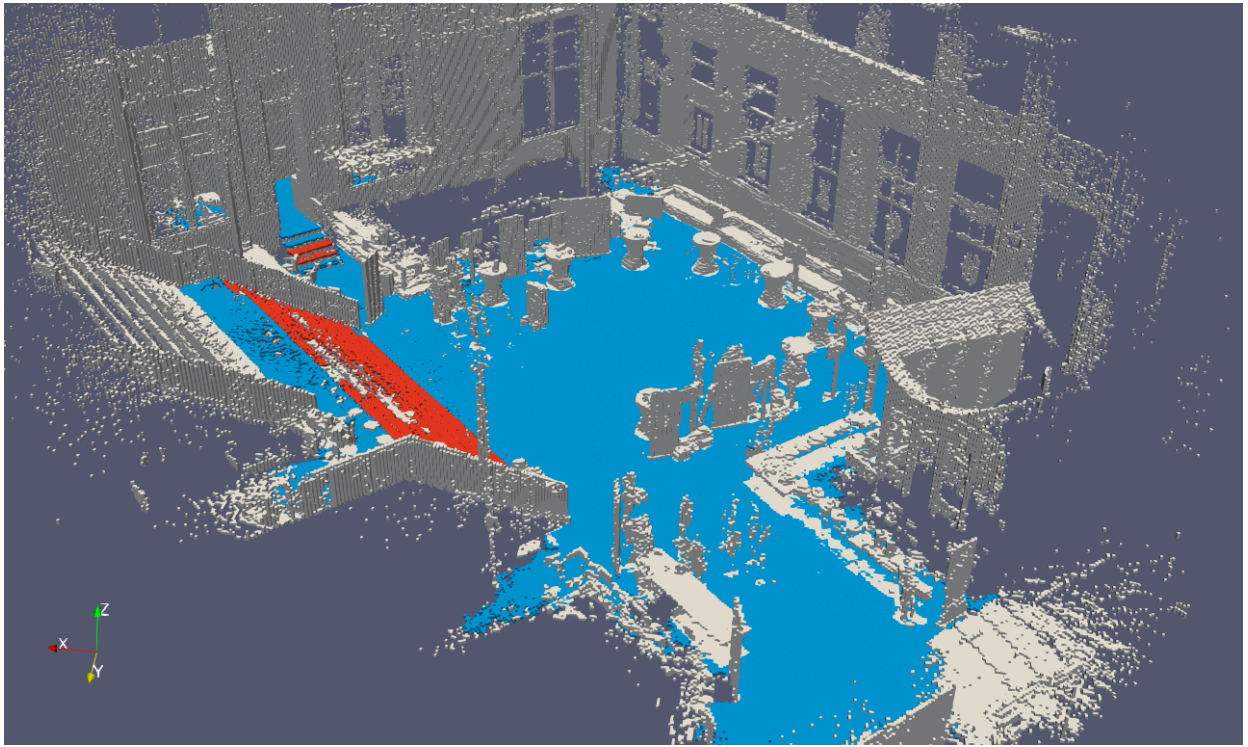
Results: navigable space



Results: navigable space



Results: navigable space



Research question

Which indoor walkable space can be identified from a voxelized point cloud using the trajectory of a mobile laser scanner?

- Possible to detect: stairs, slopes and horizontal walkable space
- M^2 accuracy of 10%
- Identification entryways: split building into spaces

Future work

- Identification of walls
- Identify types of furniture elements
- Identification of dynamic objects, which do not move during the scanning
- Generation of a node network (network graph)

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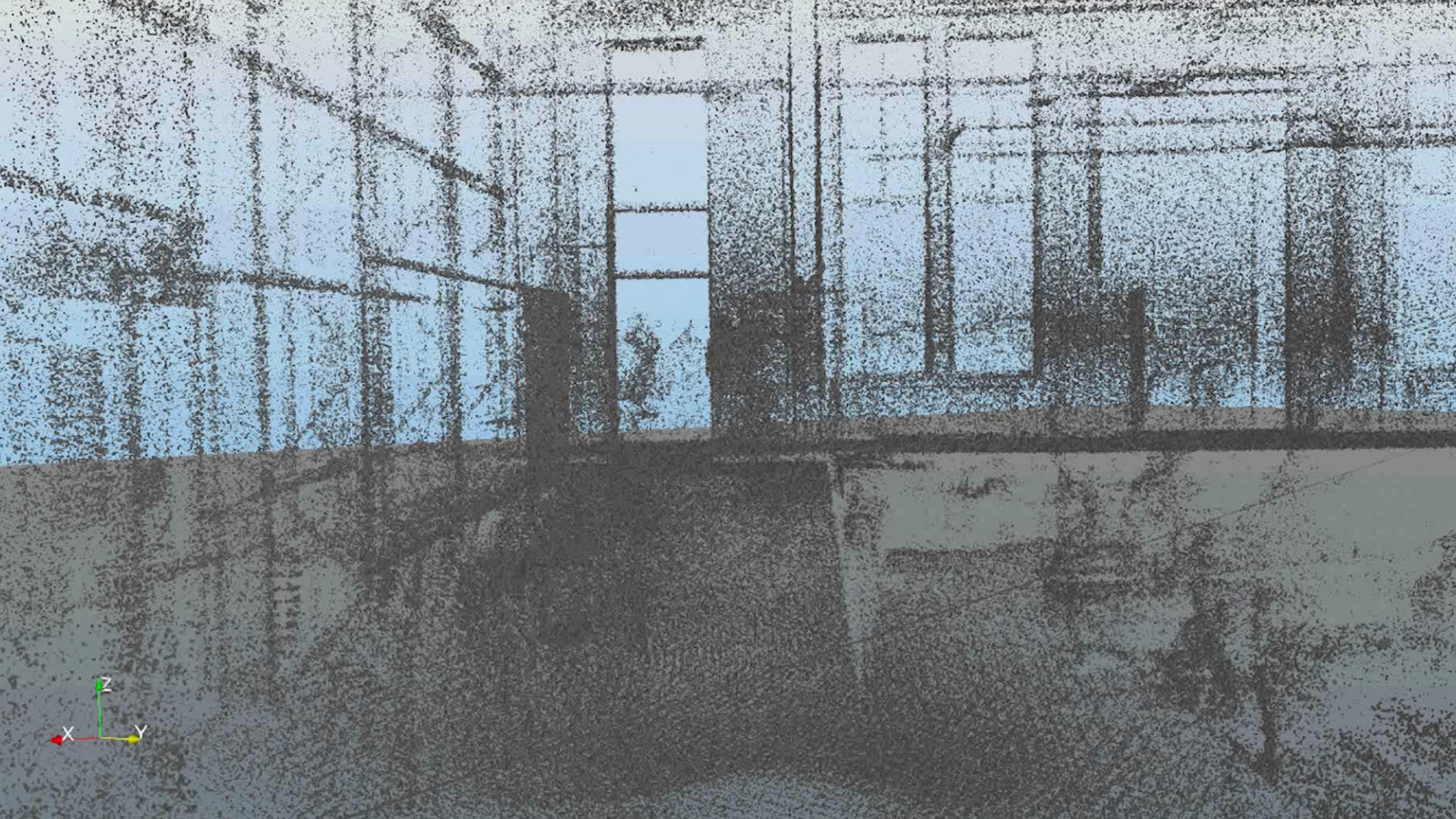
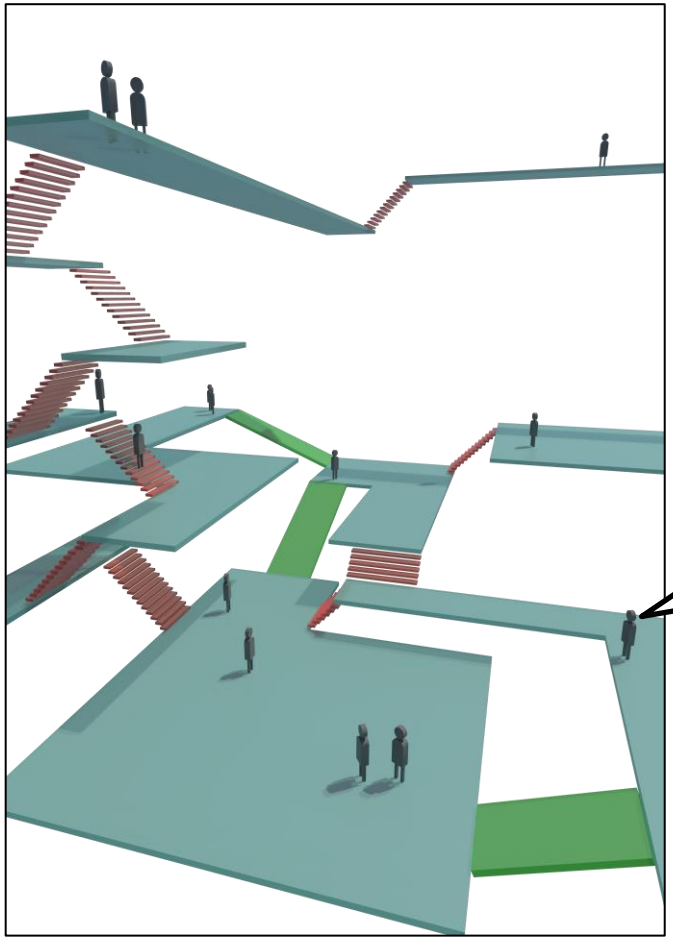

Z
X
Y



Thank you
for your attention!

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