Permanent Structure Detection in Cluttered Point Clouds from Indoor Mobile Laser Scanners (IMLS)

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Problem and Motivation:

- Permanent structure reconstruction, wall detection, room classification
- Opening detection from cluttered data: door, window
- Applying current methods on MLS data
- Topology reconstruction
Related Work:

- **Wall detection:** wall is a permanent structure dividing 3D space
  Methods: 2d histogram (Adan & Huber, 2011), normal vector (Sanchez and Zakhor, 2012), cell decomposition (Mura et al., Oesau et al., Xiao and Furukawa, 2014; Ochmann et al., 2016), density histogram (Iro Armeni et al. 2016)
  Problems: excess wall detected, some walls are missed, clutter close to walls, occlusion

- **Opening detection from cluttered data:** ray-tracing (Adan & Huber, 2011)
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Objectives and Workflow:

• Wall detection using topology relation
• Opening detection using occlusion test
• Door detection in voxel space using trajectory
• Room classification
• Improving permanent structure

- Segmentation
- Intersect segments
- Labeling: segment is labeled as wall:
  \[
  \text{iff } \text{is connected to the ceiling AND other walls}
  \]
- Check the result with room candidates
Wall detection result:

Zeb1 data from Fire brigade building (top view)
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Opening detection: Opening detection using occlusion test (Adan & Huber, 2011)

- Point clouds from Zeb1 and NavVis M3
- MLS trajectory as sensor position

Zeb1 data from Fire brigade building (top view)
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**Opening detection**: Opening detection using ray-tracing

Point clouds and trajectory

Point clouds and trajectory (top view)

Candidate surface points (front view)
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**Opening detection**: Opening detection using occlusion test

- Generate planar voxel grid from candidate surface
- Label voxels as occupied and unoccupied

![Surface point cloud (front view)](image)

![Voxels (front view)](image)

- Occupied
- Unoccupied
**Opening detection:** Opening detection using occlusion test

- A voxel on the wall is opening if there is a point behind the wall, otherwise occluded.
**Door detection:**

- Voxelize the point clouds
- Find open door centers with three rules:
  1. A door center is in empty space
  2. Above the door center there are points
  3. There should be a trajectory close by
- Extract door borders
- Extract closed doors
  For closed doors trajectory goes through a wall

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Front view: point clouds containing two doors

Closed door (front view)

Trajectory (white) and door centers (red)
Results: Fire brigade building 3rd floor
Room classification and navigable space:

- Store empty space within a margin of clutter and walls between floor and ceiling
- Store Navigable space above the floor (right image)
- Subdivide the empty space with door locations (left image)

Top view of empty spaces. Black areas representing walls and clutter.

Navigable space just above the floor. Yellow circles are location of doors.
Room classification and navigable space:

- Store empty space within a margin of clutter and walls between floor and ceiling
- Store Navigable space above the floor (right image)
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Room classification and navigable space:

- Store empty space within a margin of clutter and walls between floor and ceiling
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Analyzing the methods:

- **Wall Detection**: relies on the segmentation 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.
- **Room Classification**: windows and gaps in the data are problematic for space subdivision.

**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 topology reconstruction
- ... ???
Conclusion and further work:

- Changing the **order** of steps and **iteration** is expected to improve the results.
Future Plan:

- Evaluate the result of the object detection
- Improving the topology and geometry of the generated model
- Design the shape grammar rules
- Apply the shape grammar on the generated model for large buildings
Thank You for your Attention

Questions?

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