Procedurally Generated and Digitally Recreated Environments Designed for Interactive Content in Augmented and Virtual Reality

Jan-Philipp Fahlbusch

May 2020

Final: Master Informatics: Games Engineering

Supervisor(s): Prof. Gudrun Klinker, Sven Liedtke

Motivation

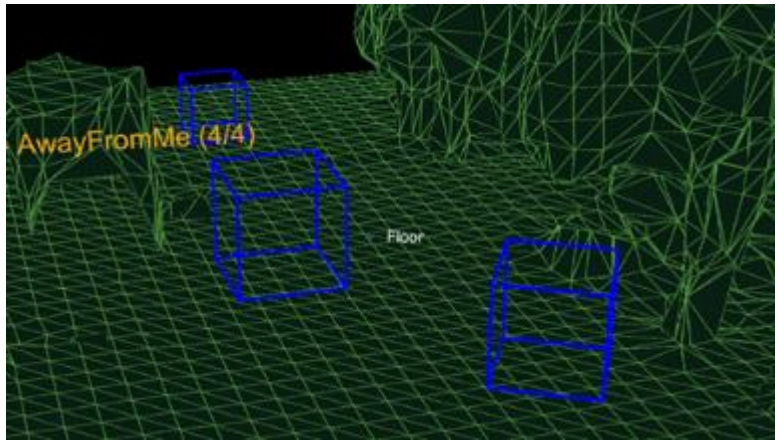
Introduction

- Build foundation to automate environment creation for room scans
  - Recognize and simplify room boundaries

- Place objects automatically in environment based on detected features
  - Classify and define suitable locations for interactive content

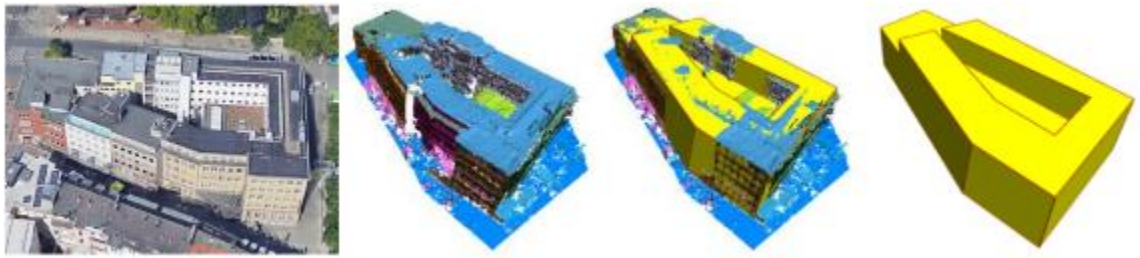
Problem Description: Issues

- **Room Creation**:
  - Future of VR is without cables
  - Need a reliable method to recreate the actual boundaries digitally
  - Require diverse environments



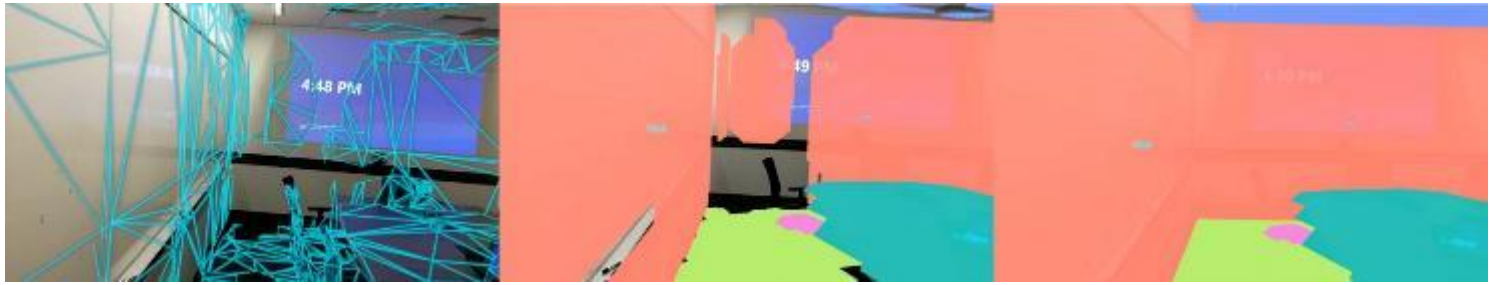
- **Interactive Content Placement**
  - Need to categorize the environment
  - Depending on interactive content, spawn at suitable location
- **Universal Solution**
  - Needs to run on different platforms (HoloLens UWP, VR Windows App)
  - Should run in all development environments for these platforms (Unity, Unreal, etc.)

Related Work



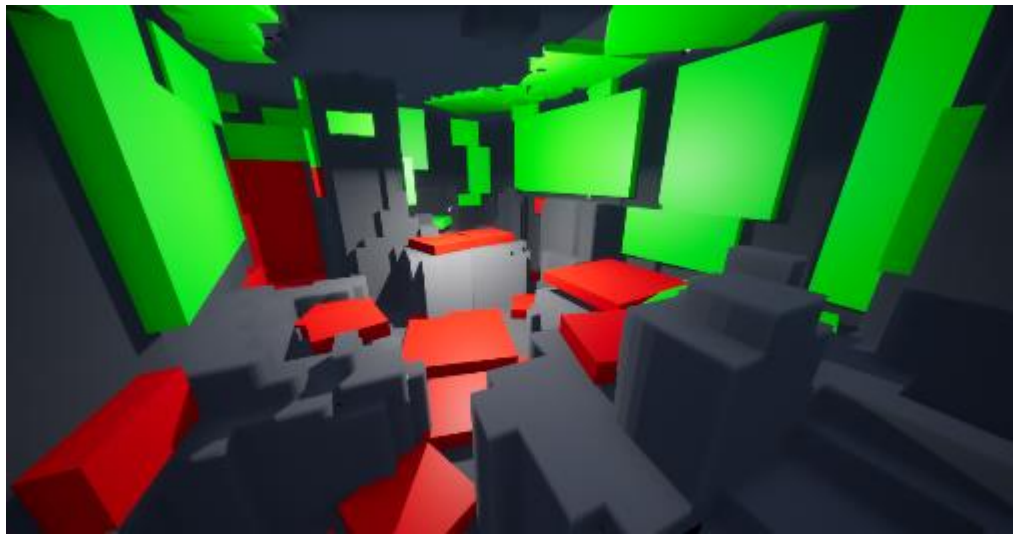
- **Room Generation**:
  - Room Recreation ([2, 6, 7])
  - Placing models over room scan ([8, 9, 10, 11, 12, 13])
- **Mesh Understanding**:
  - Some for HoloLens and Rooms ([1, 2, 14])
  - Some for general 3D meshes ([3, 4, 5])
  - None for suitable locations for interactive content

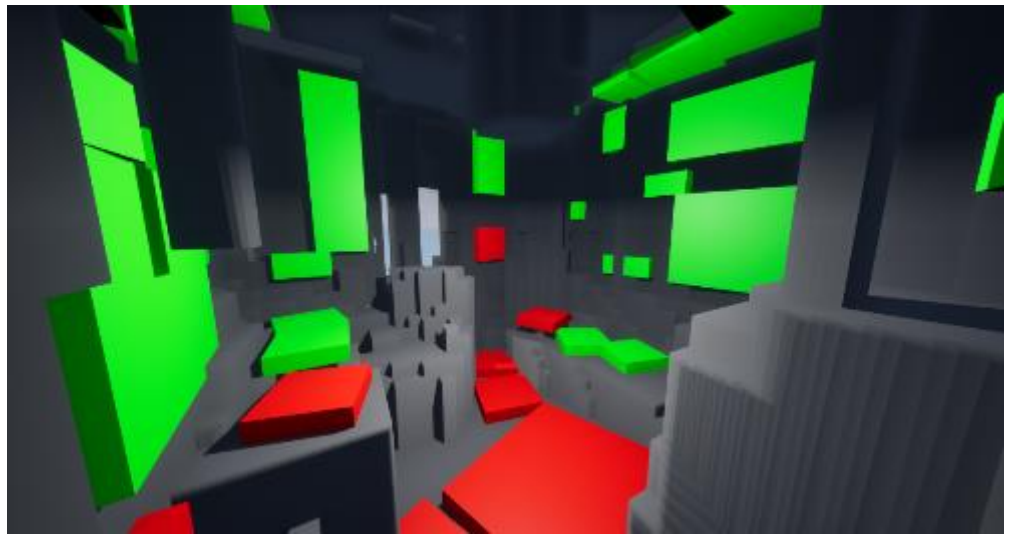
- **Universal AR/VR Solution**:
  - None for both
  - None in real-time for both



Goals of this Thesis

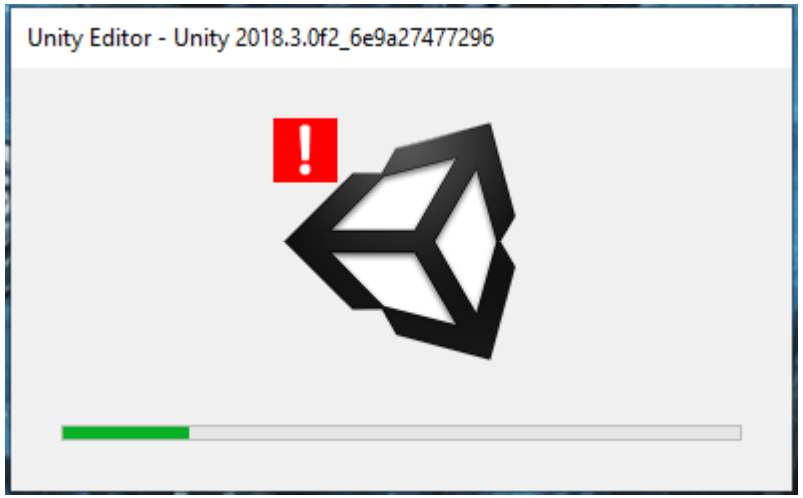
- Identify and automatically classify suitable areas for interactive content
- Automatically create very simplified room bounds for easy further processing of the room geometry
- Deliver results in real-time, even on low-end AR hardware





Critical Research Issues

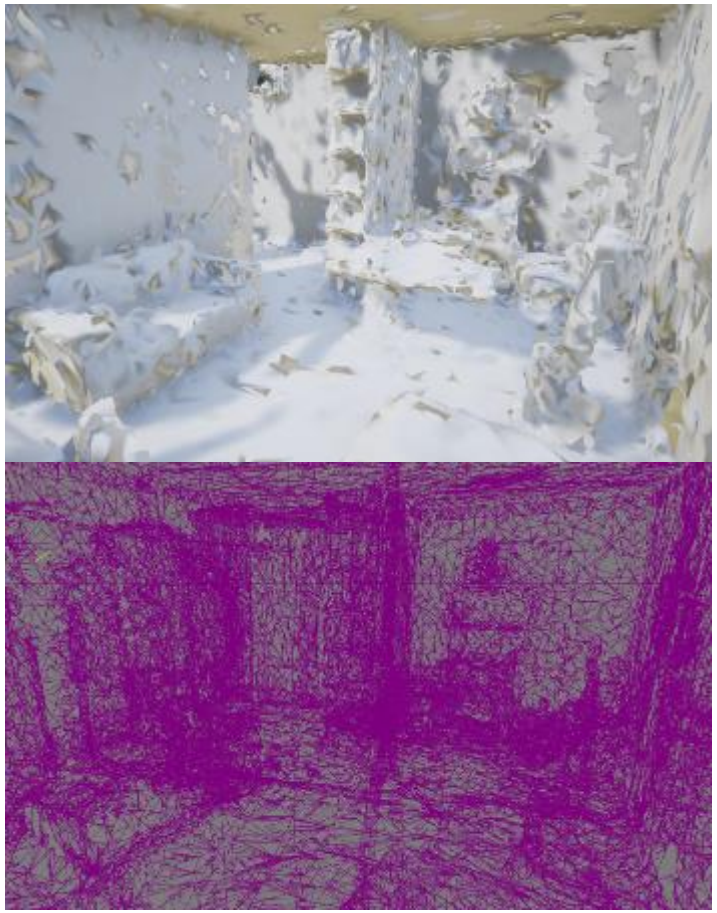
- Only using C++ Standard Library
- Compatibility with Unreal and Unity
- Deliver room understanding results in real-time
- Only a point cloud of the room to extract features from

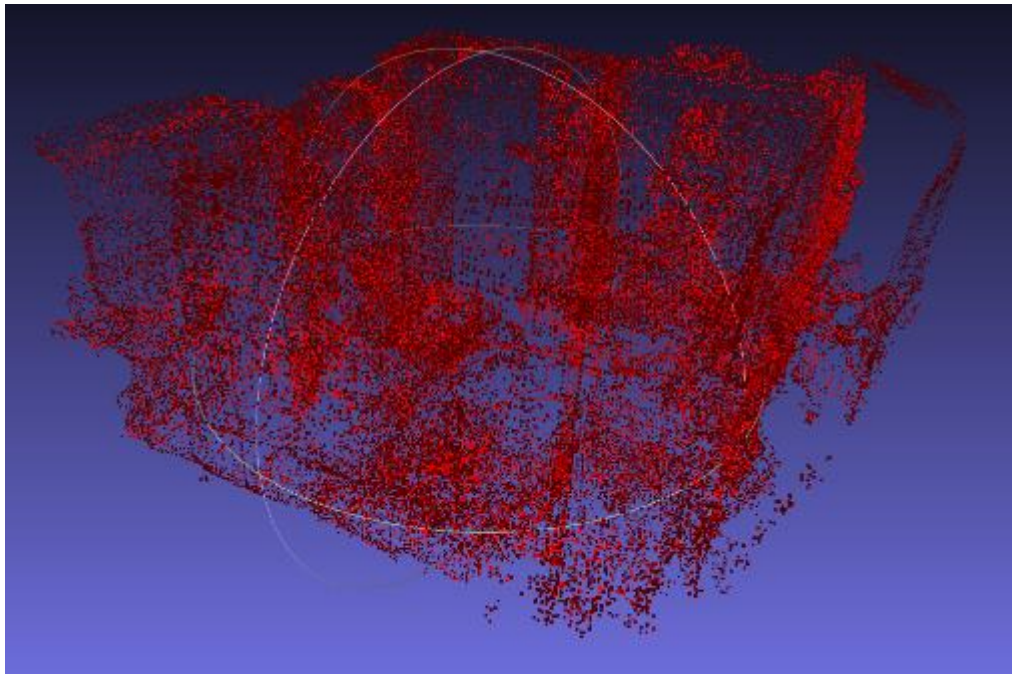


Proposed Work

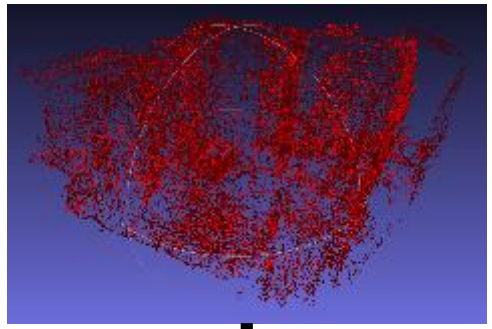
- Create a plugin in C++ that is compatible with Unreal, Unity, etc.
- Use existing hardware and methods to scan the room (HoloLens, ZED mini)
- Evaluate spatial understanding algorithms to be used in AR and VR
  - Implemented our own solution to meet our needs
- Implement procedural generated and digitally recreated environments
  - Implemented the recognition and simplification of room boundaries
- Research and implement categorization algorithm for interactive content
- Provide real-time solution

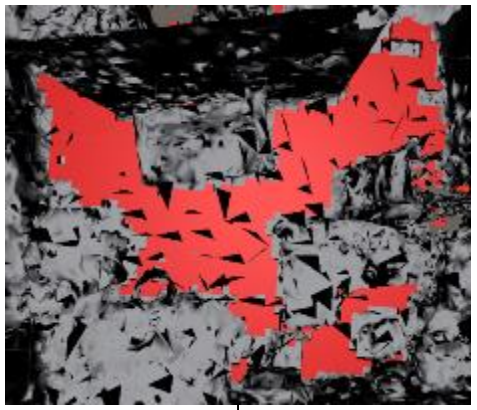
Implementation – Preprocessing





Implementation – Room Understanding





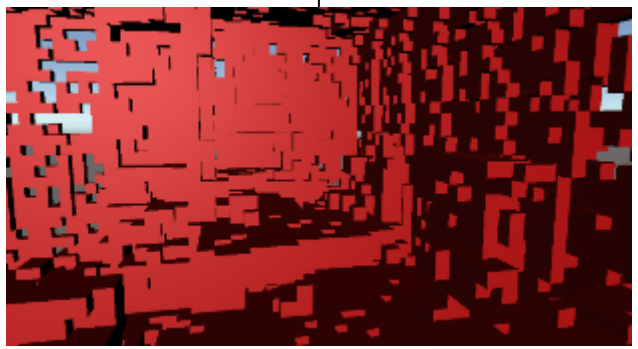
Voxelize Representation

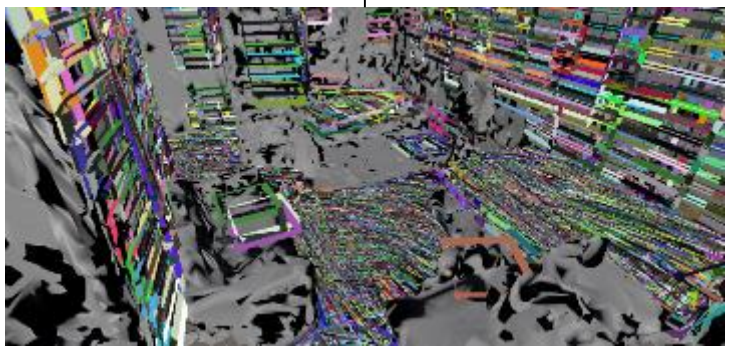
Extract Important Features

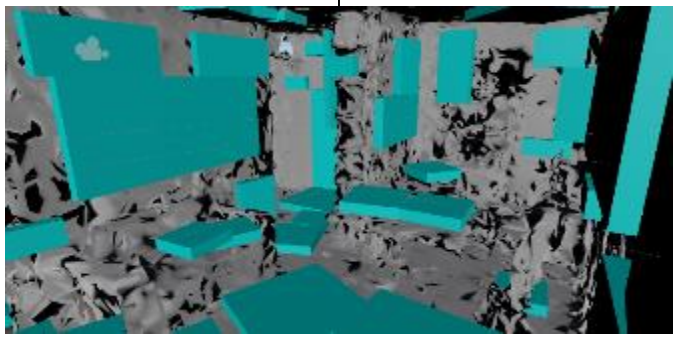
Define Suitable Areas

Reduce Results

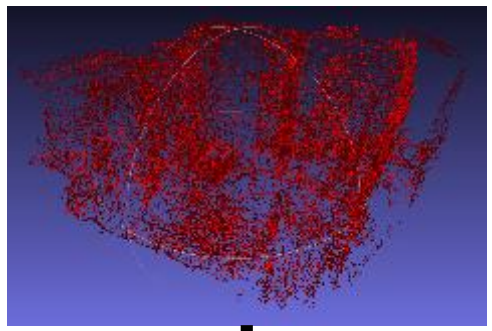
Categorize Results

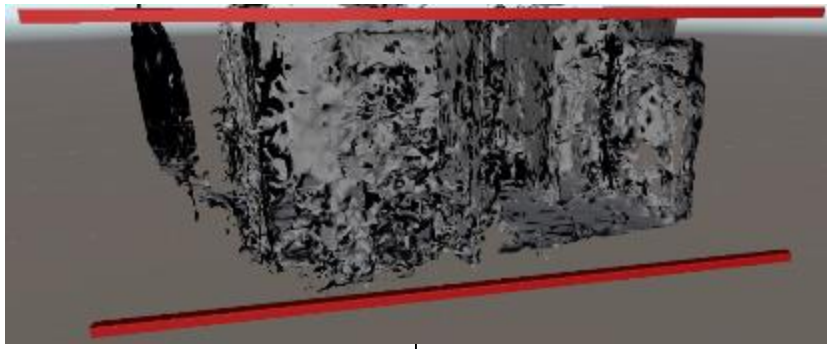






Implementation – Room Recreation



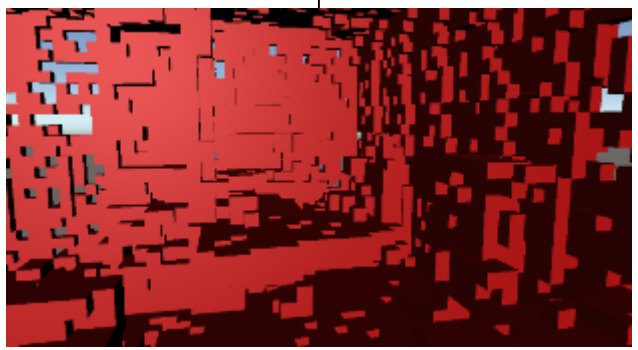


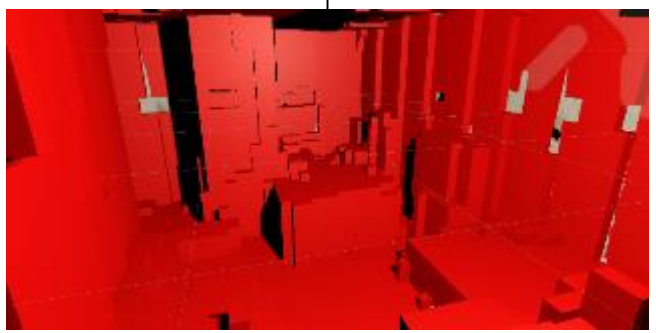
Voxelize Representation

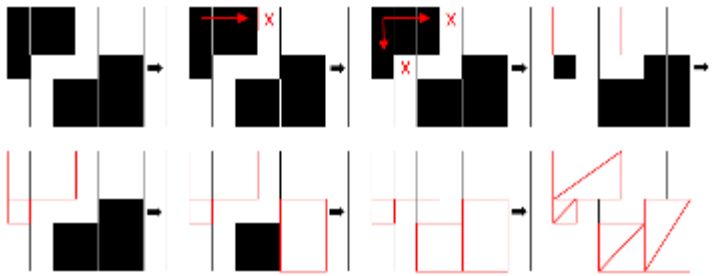
Extract Important Features

Create Bounding Volume

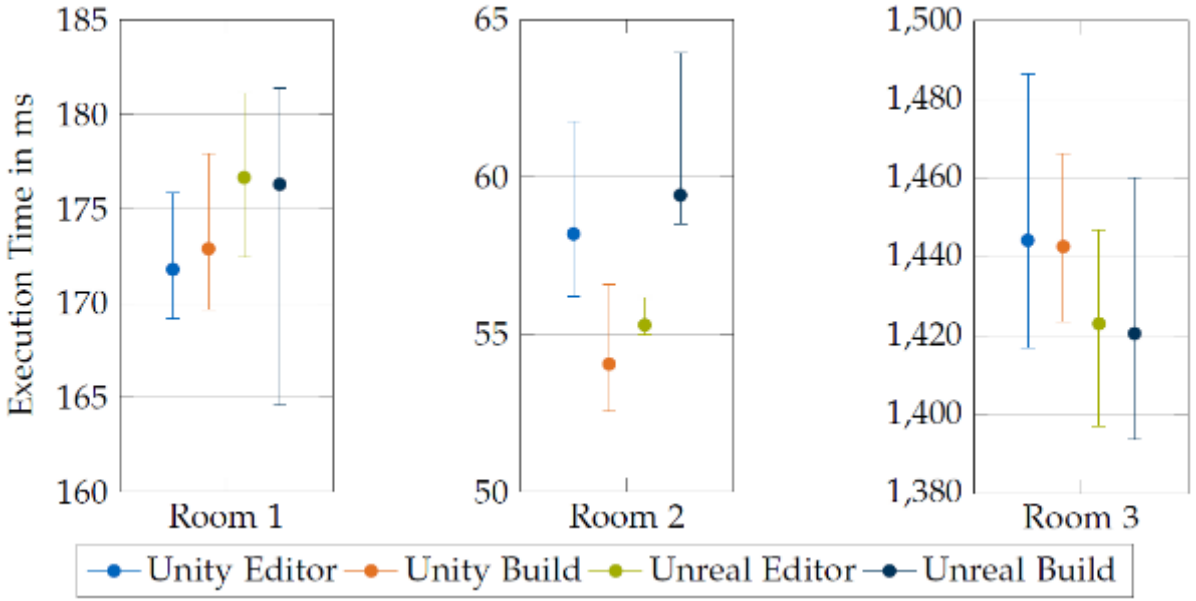
Generate Mesh

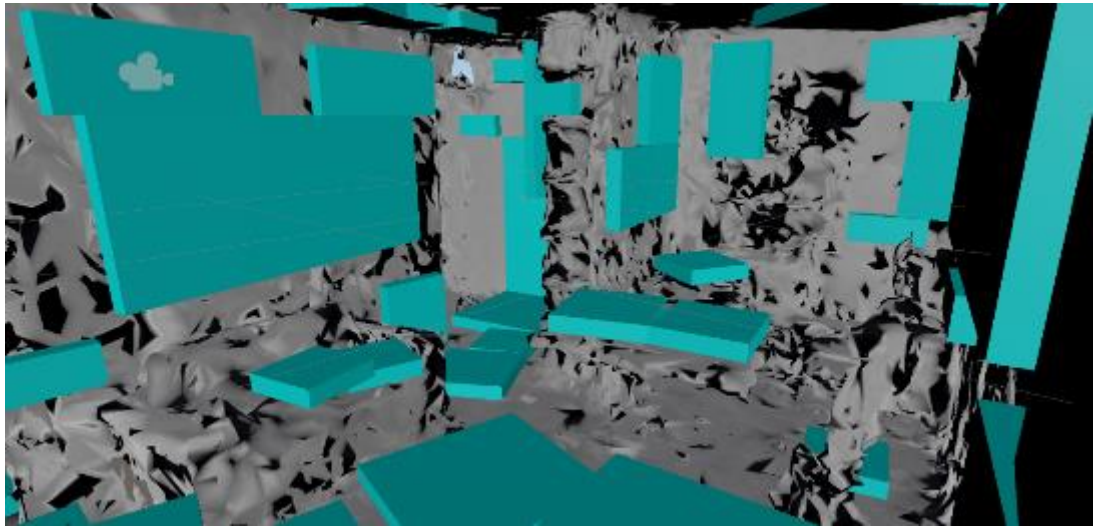






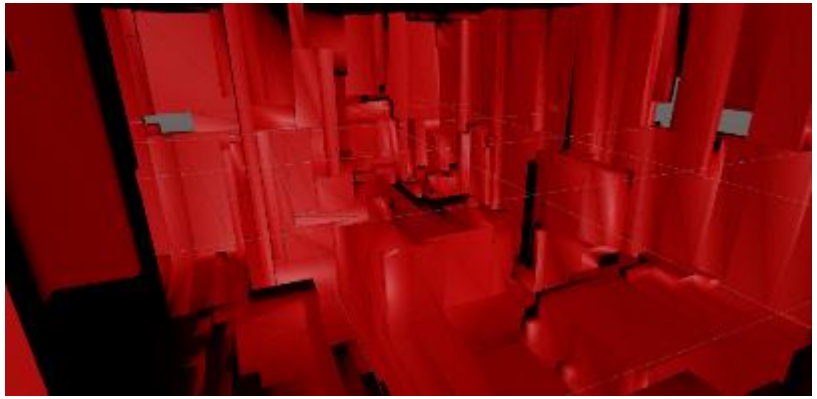
Evaluation – Room Understanding

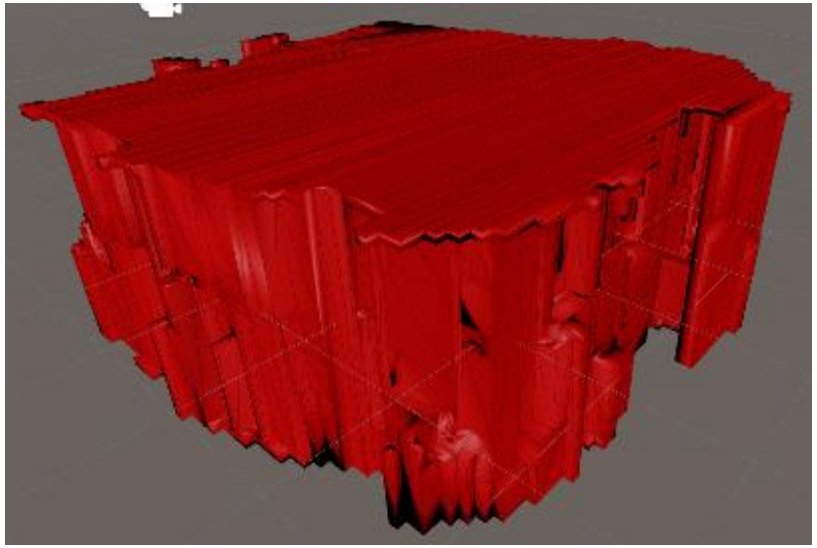


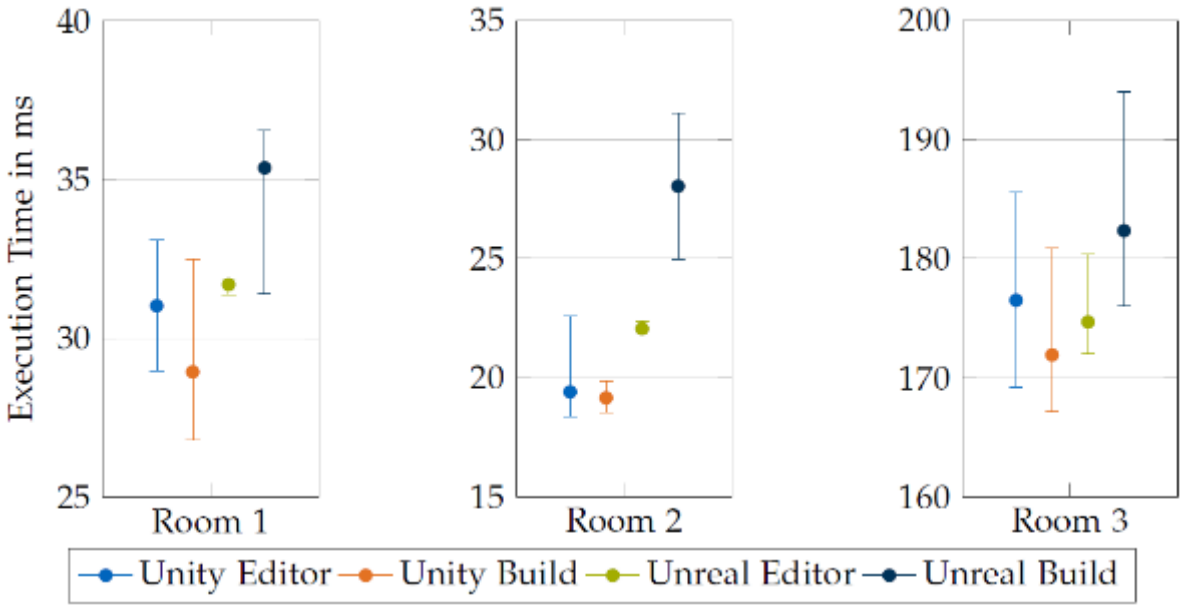


	Room 1	Room 2	Room 3
Areas Detected	116	75	227

Evaluation – Room Recreation

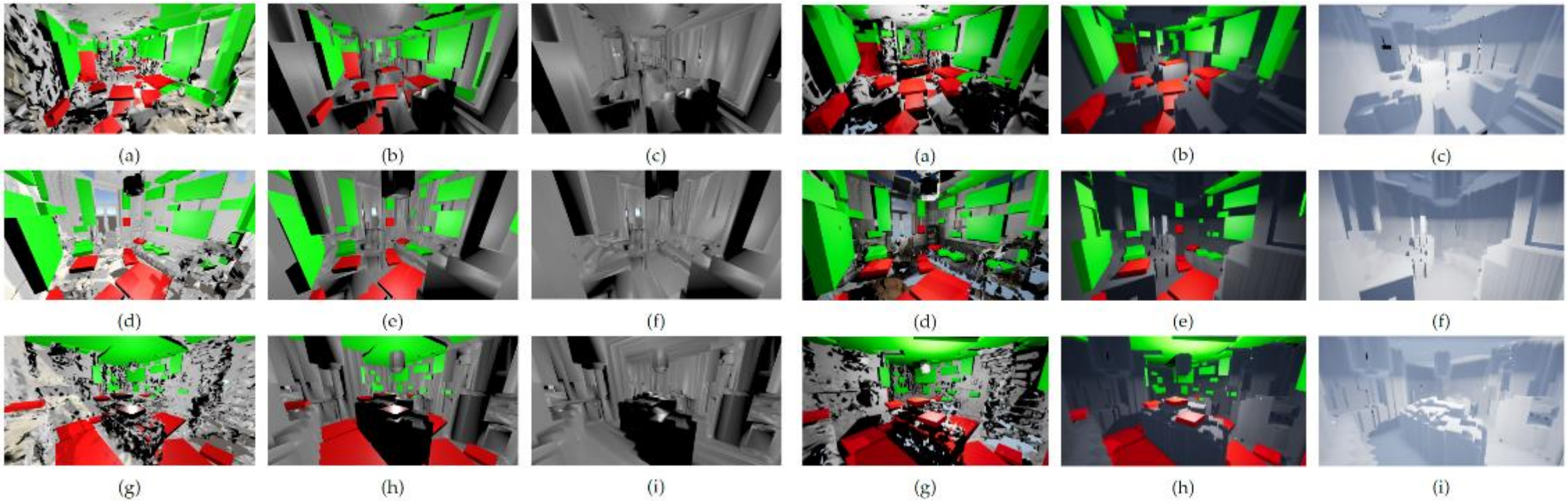






		Room 1	Room 2	Room 3
Vertices	Original	78,430	332,088	232,097
	Reduced	4,770	2,524	11,664
Triangles	Original	131,178	110,696	385,207
	Reduced	6,812	3,608	16,702

Evaluation – Comparison Unity and Unreal



Unity

Unreal

Live Demo

Future Work

- Test on more AR and VR hardware
- Look into performance in a productive environment
- Expand approach for currently unhandled cases
- Evaluation of impact for each step from the algorithm
- Scalability improvements for large rooms

- Create environment automatically based on room bounds
- Place interactive content automatically in suitable areas

Conclusion

- Provided an algorithm that detects features in a room
- Define and categorize suitable areas in a room
- Takes less than 200 ms for normal room

- Can detect and recreate room boundaries in less than 40 ms
- Reduce room geometry to a fraction of original scan

- Deterministic nature of algorithms
- Usable on any software supporting C++ DLLs

Questions?

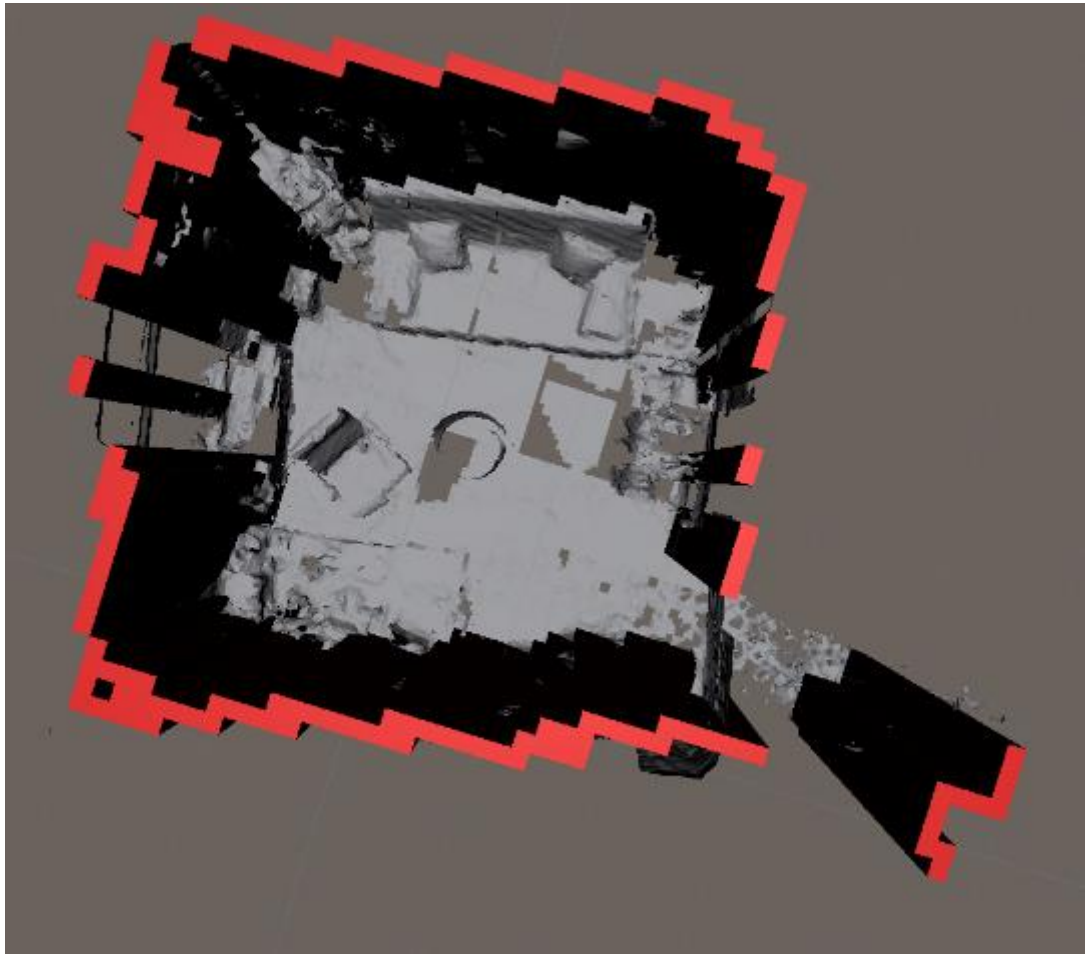
List of References

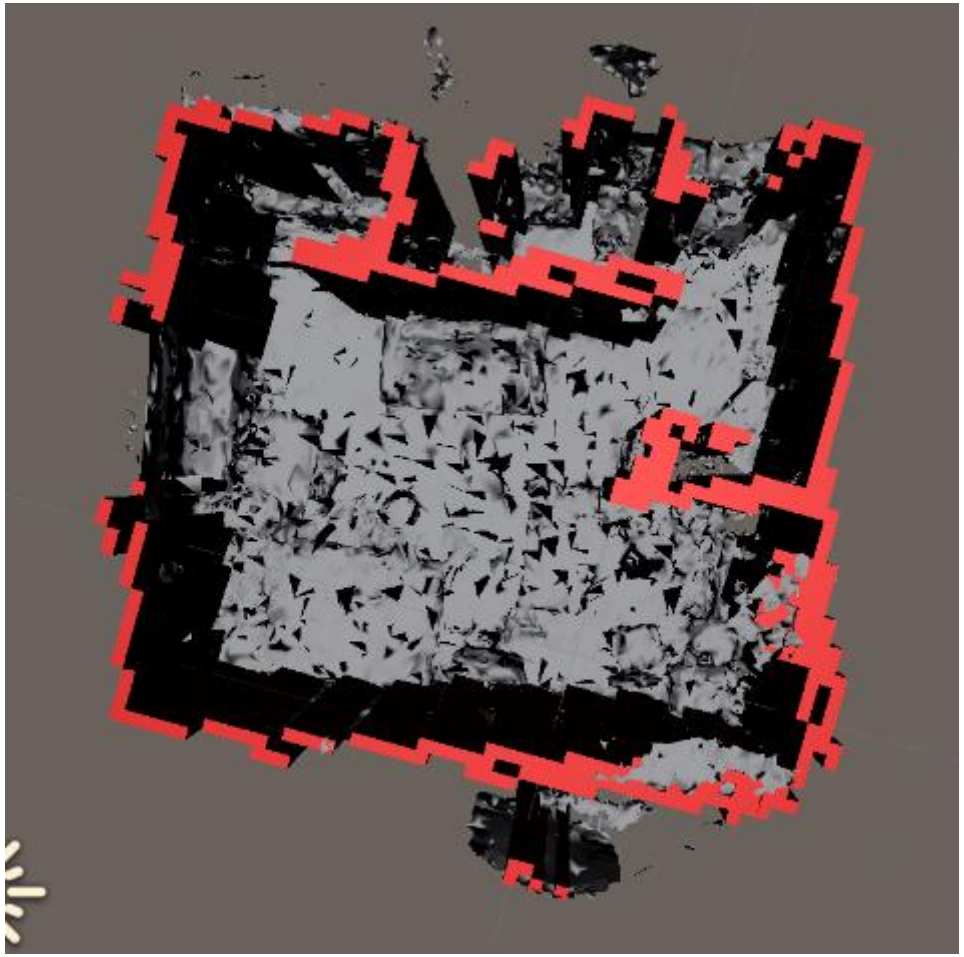
1. https://github.com/microsoft/MixedRealityToolkit/wiki/HoloToolkit.SpatialUnderstanding
2. https://pdfs.semanticscholar.org/a69d/73da83a6ca2c7bfd506c77c1f4009d9a76c8.pdf
3. https://dl.acm.org/citation.cfm?id=2835487
4. https://ai.facebook.com/blog/pushing-state-of-the-art-in-3d-content-understanding/
5. https://arxiv.org/pdf/1904.09664.pdf
6. https://www.stereolabs.com/zed-mini/
7. https://docs.microsoft.com/en-us/windows/mixed-reality/spatial-mapping
8. https://arxiv.org/pdf/1904.12012.pdf
9. https://arxiv.org/pdf/1906.04201.pdf
10. https://arxiv.org/pdf/1812.07003.pdf
11. https://arxiv.org/pdf/1811.11187.pdf
12. https://arxiv.org/pdf/1811.10464.pdf
13. https://arxiv.org/pdf/1712.10215.pdf
14. https://docs.microsoft.com/en-us/windows/mixed-reality/scene-understanding-sdk

List of Image Sources

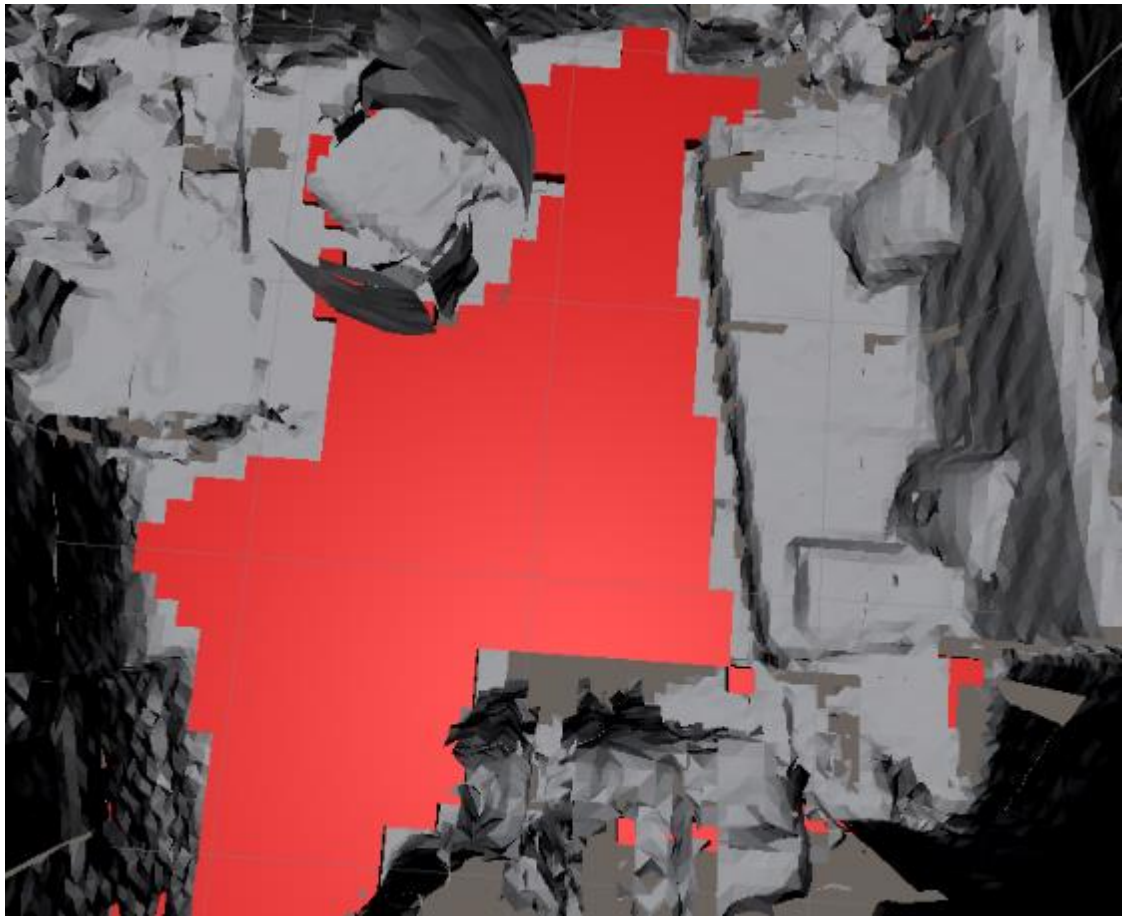
1. https://www.creativeapplications.net/wp-content/uploads/2016/04/noid-CREATE_2.jpg
2. https://i.pinimg.com/originals/f8/dd/8e/f8dd8e197be6b83b86bd01d977679553.png
3. https://images.westend61.de/0000823926l/boy-wearing-vr-glasses-playing-video-game-with-father-on-couch-at-home-EBSF02117.jpg
4. https://archive-media-0.nyafuu.org/wsr/image/1562/79/1562797810919.jpg
5. https://www.researchgate.net/publication/327604197_SEGMENTATION_OF_3D_PHOTOGRAMMETRIC_POINT_CLOUD_FOR_3D_BUILDING_MODELING
6. https://niessnerlab.org/papers/2018/3scancomplete/teaser.jpg
7. https://docs.microsoft.com/en-gb/windows/mixed-reality/images/suscenarios.png
8. https://forum.unity.com/attachments/upload_2018-12-17_19-27-39-png.345934/

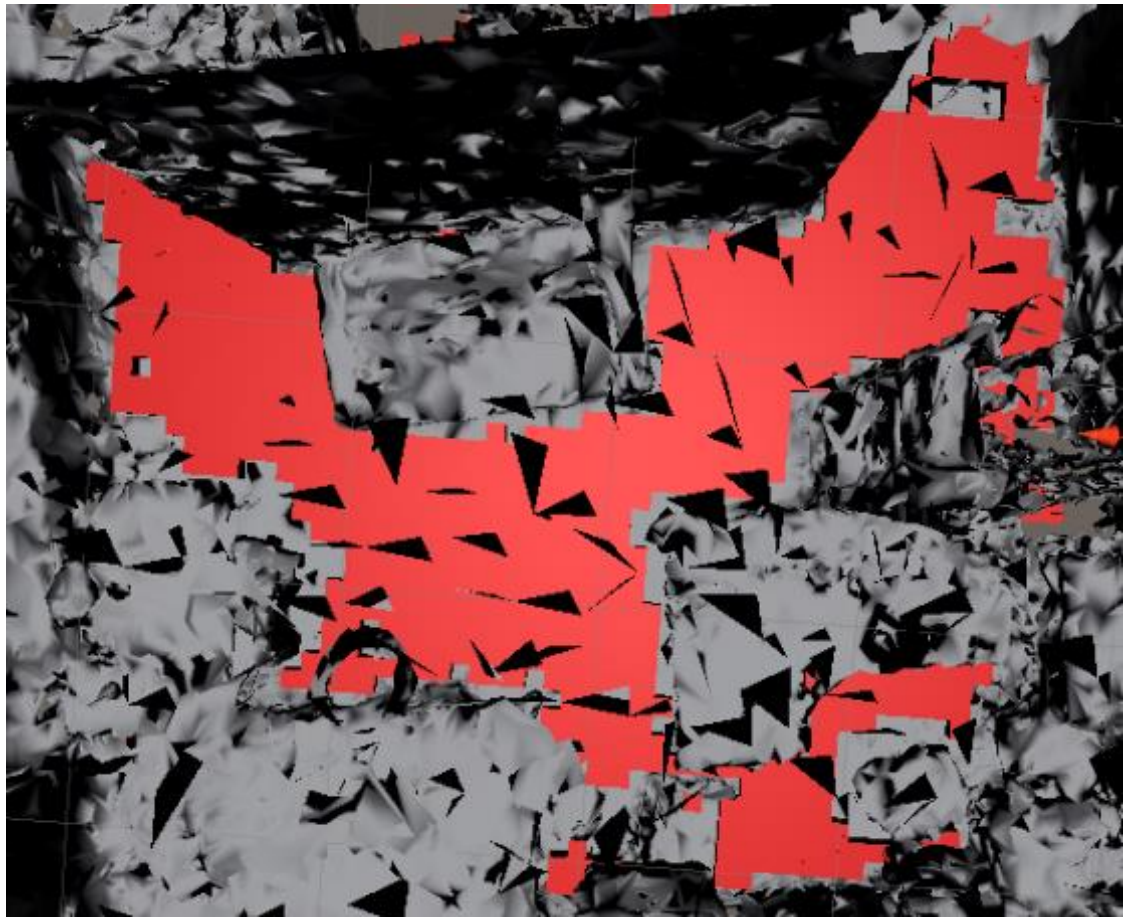
Feature Wall



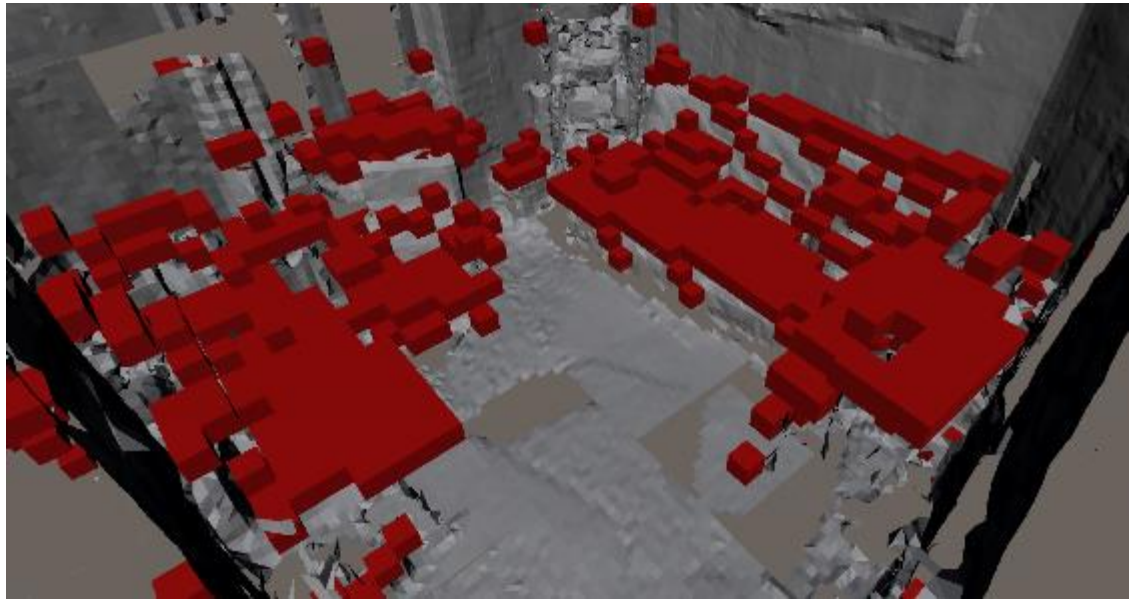


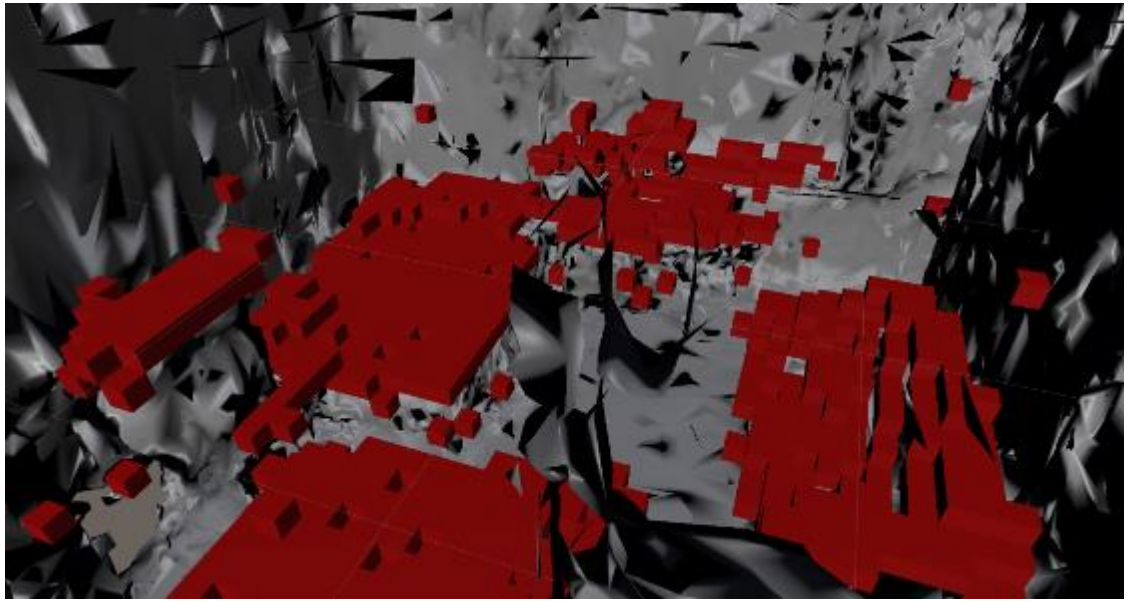
Feature Floor



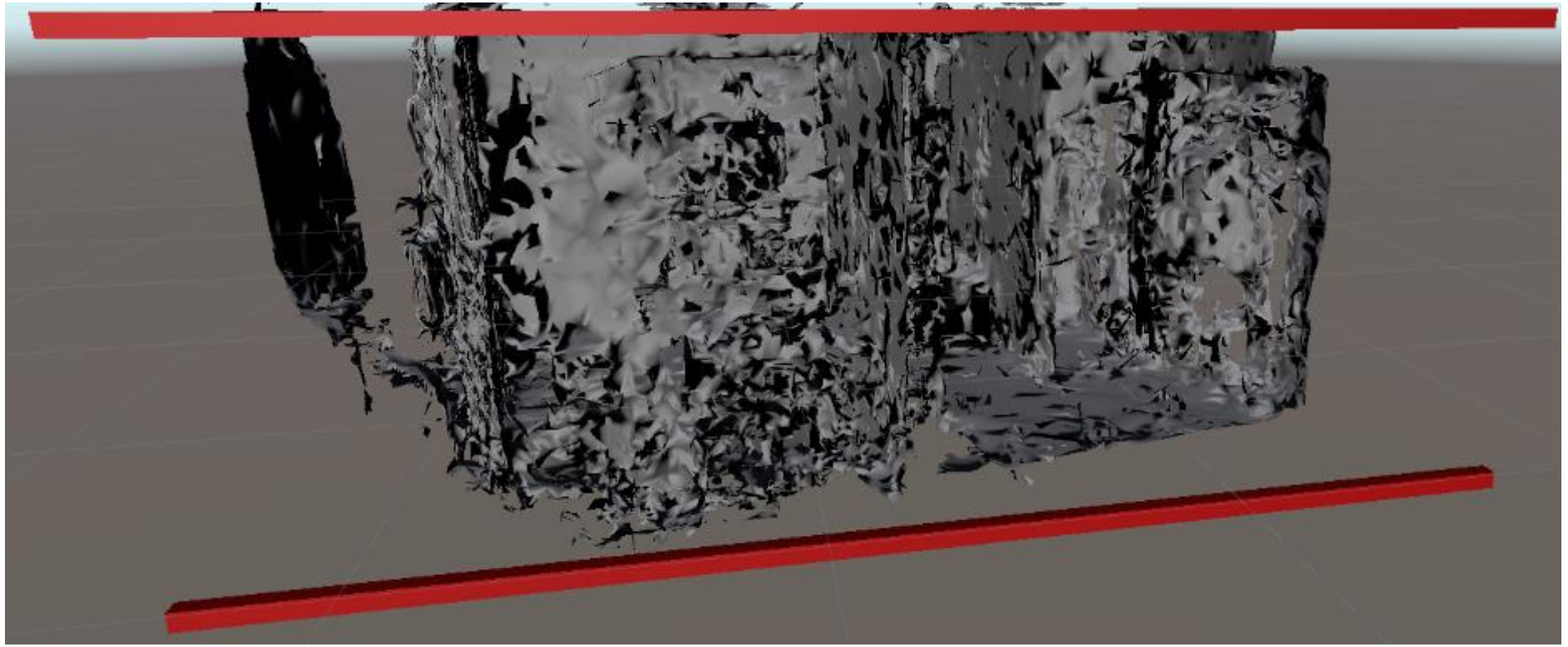


Feature Furniture





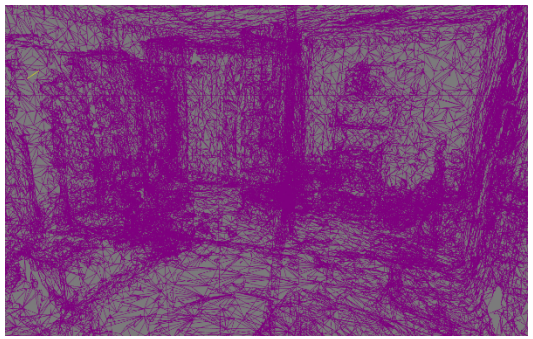
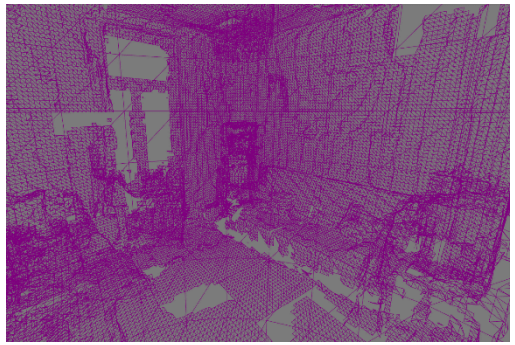
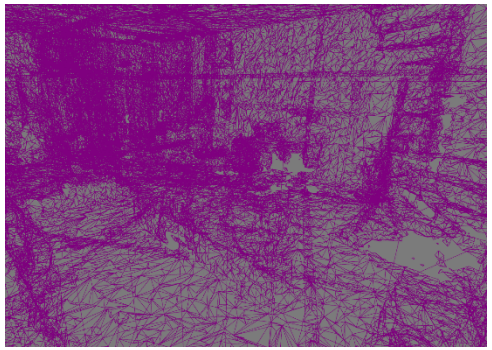
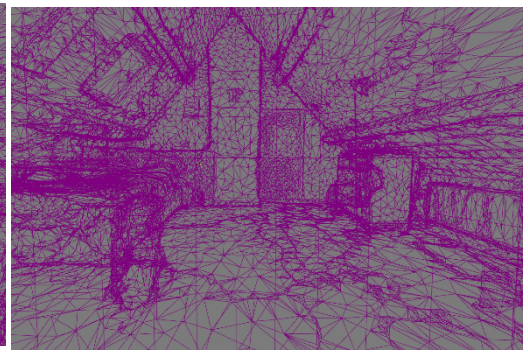
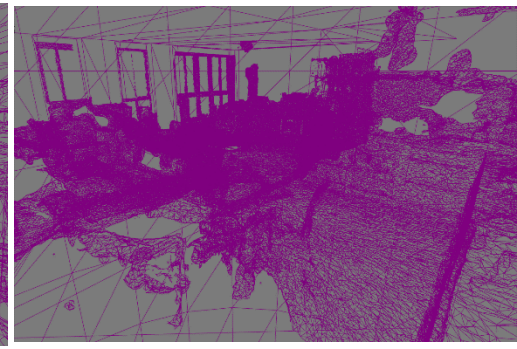
Feature Floor / Ceiling Level



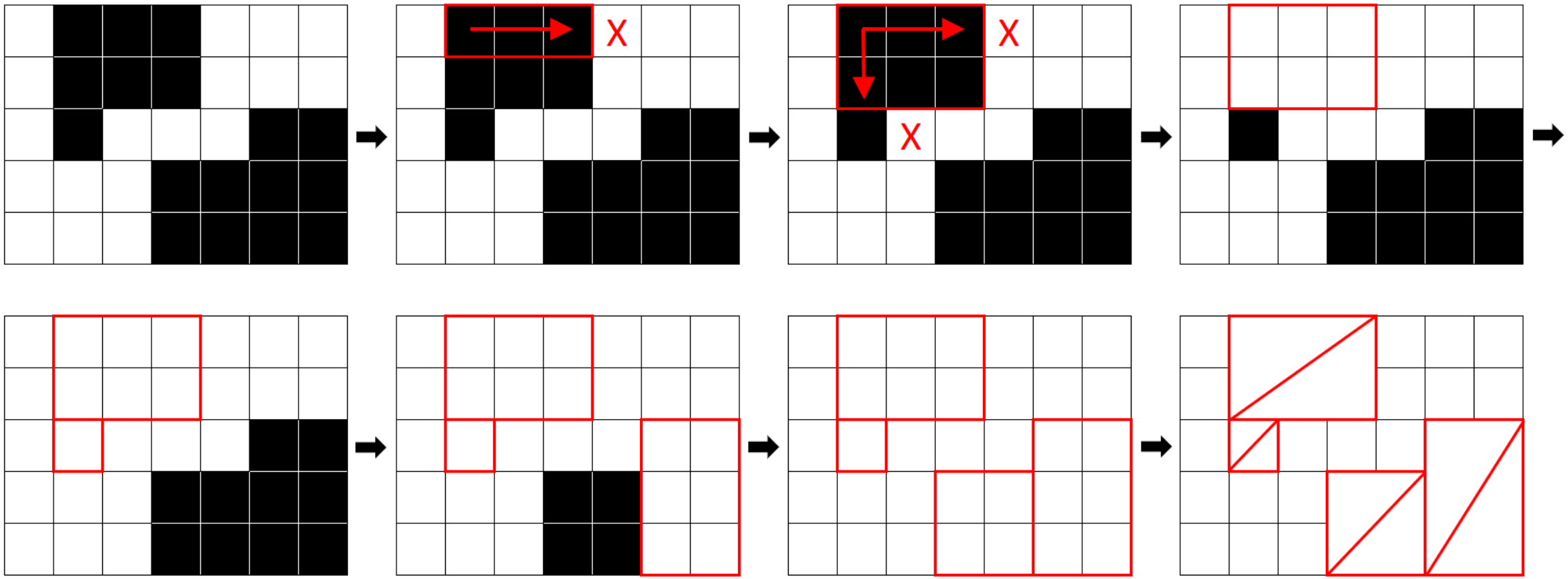
Tested Rooms



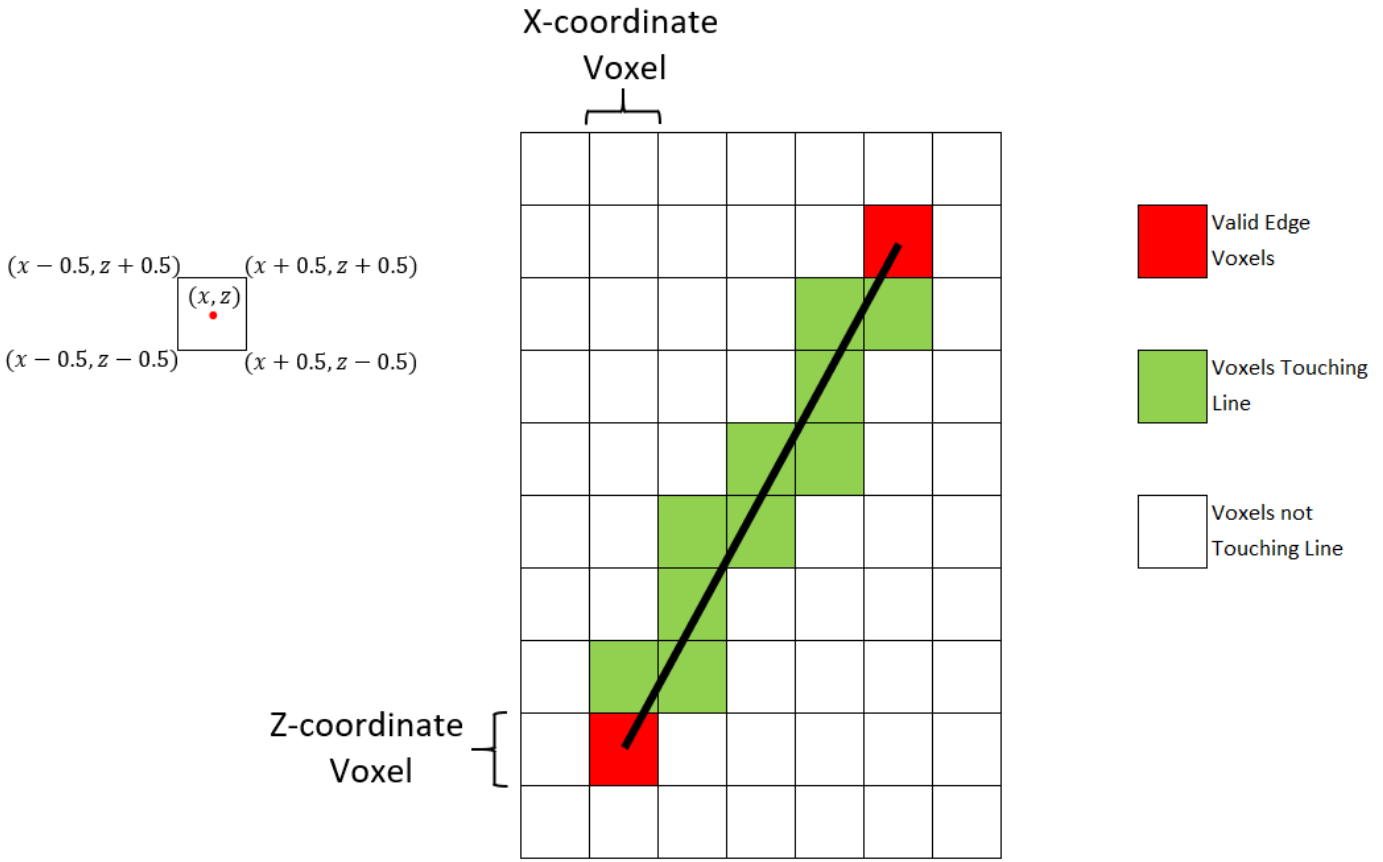


Greedy Meshing



Suitable Surface Detection Walls



Suitable Surface Detection Horizontal Areas