SCHULICH
School of Engineering

Development of an Automated Monitoring and Control System for Construction Sites

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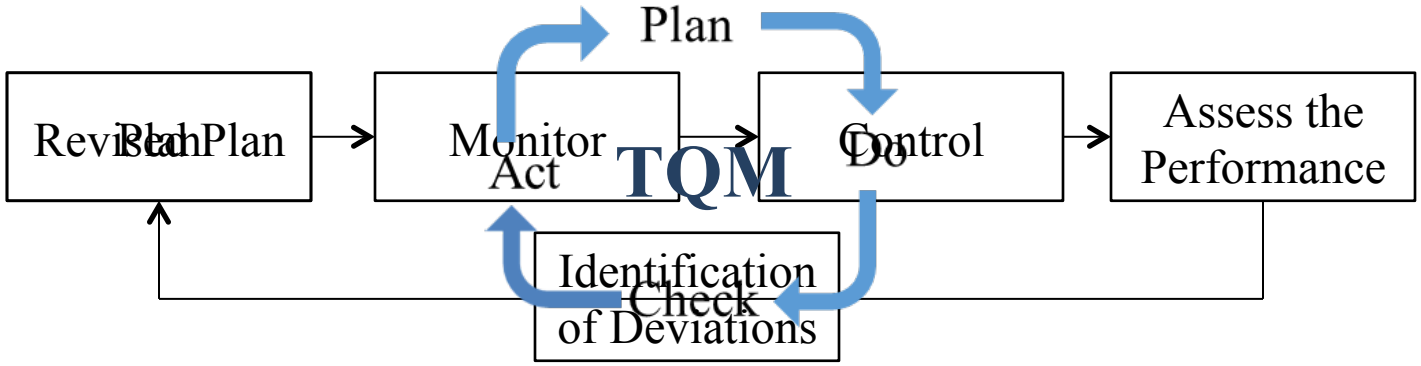
Problem Statement



- Current Monitoring Practices are mostly Manual [1] :

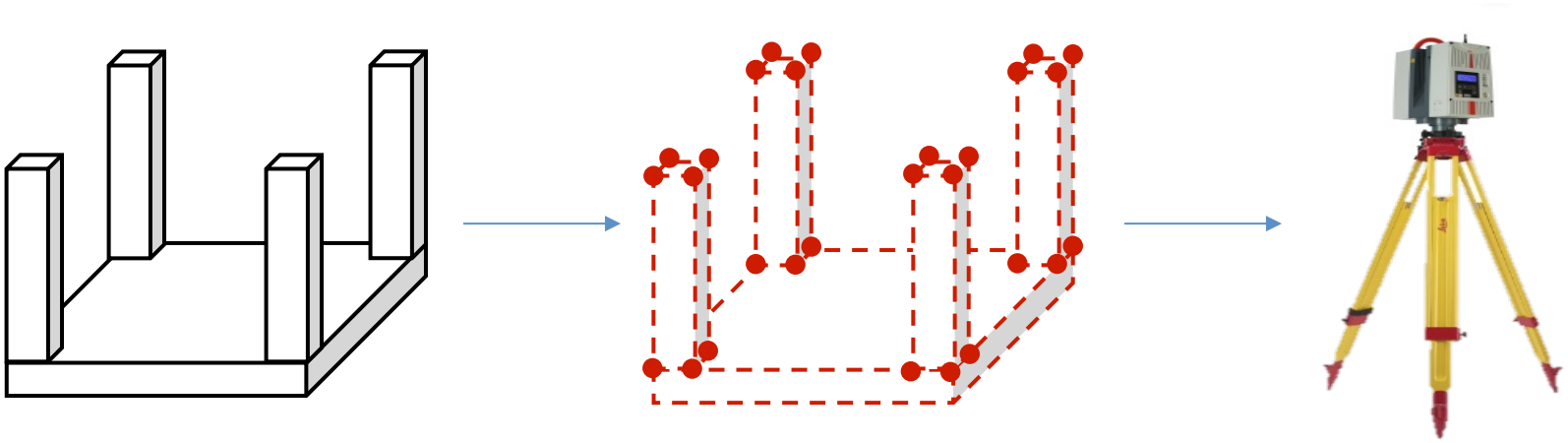
- **Safety** → Risks of most common site accidents are not decreased [5]
- **Productivity & Communication** → 40-60% of tool time is wasted [6]

  - Untimely identification of causes of delays and cost overruns [2]

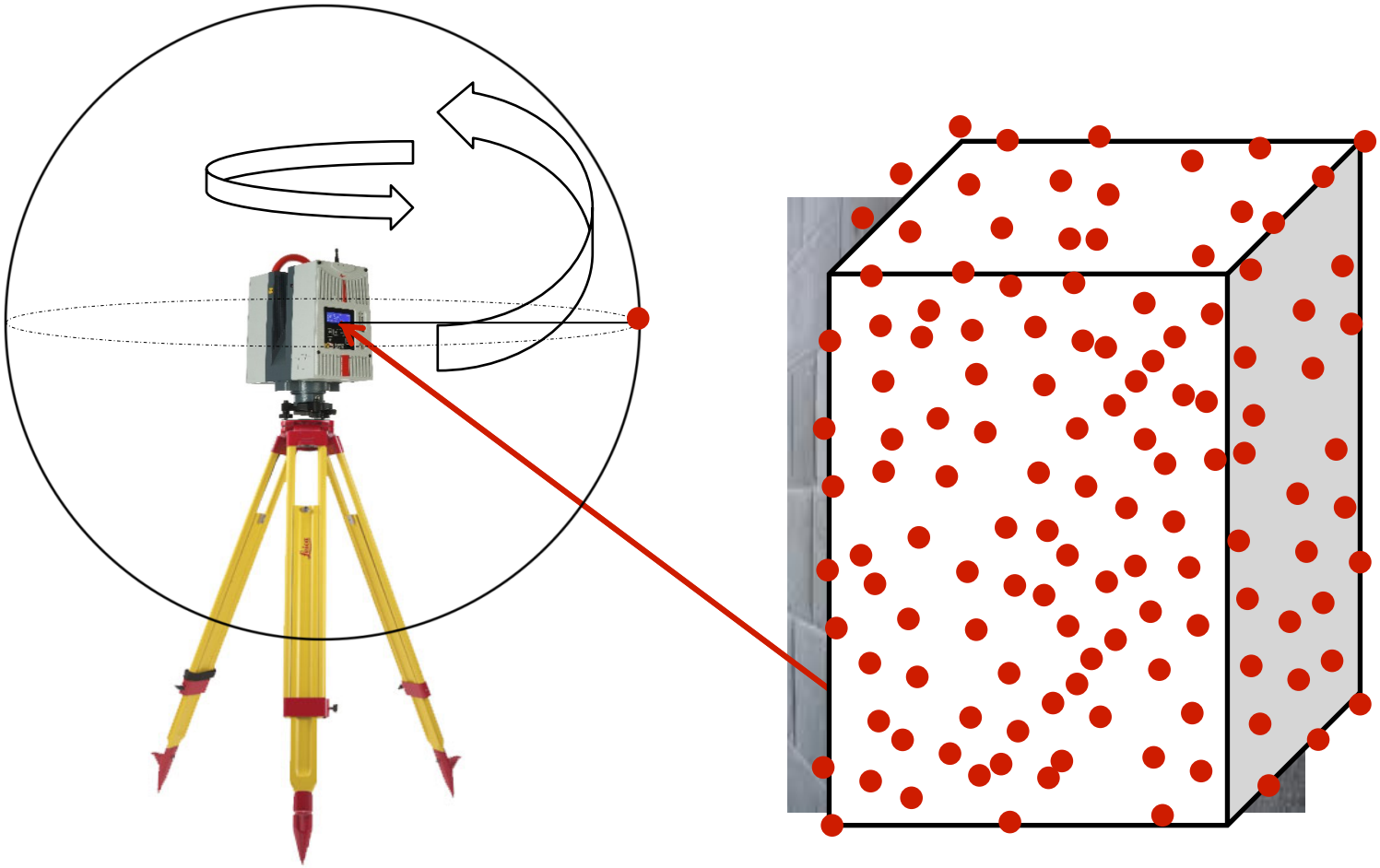
- Site supervisors spend **30-50%** on analysing the data [3 & 4]

Research Objective

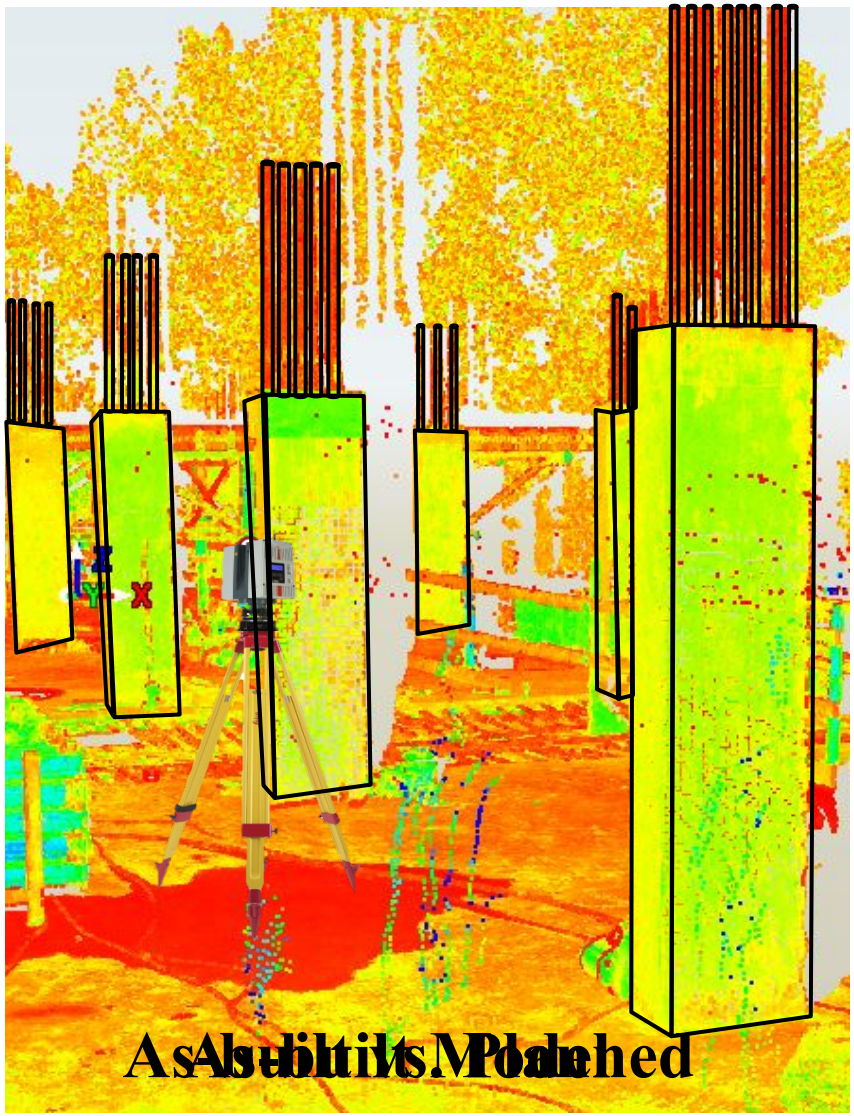
- To Automate the Monitoring and Control Process
  - Automated Monitoring to determine:



Overview of LiDAR



Research Method



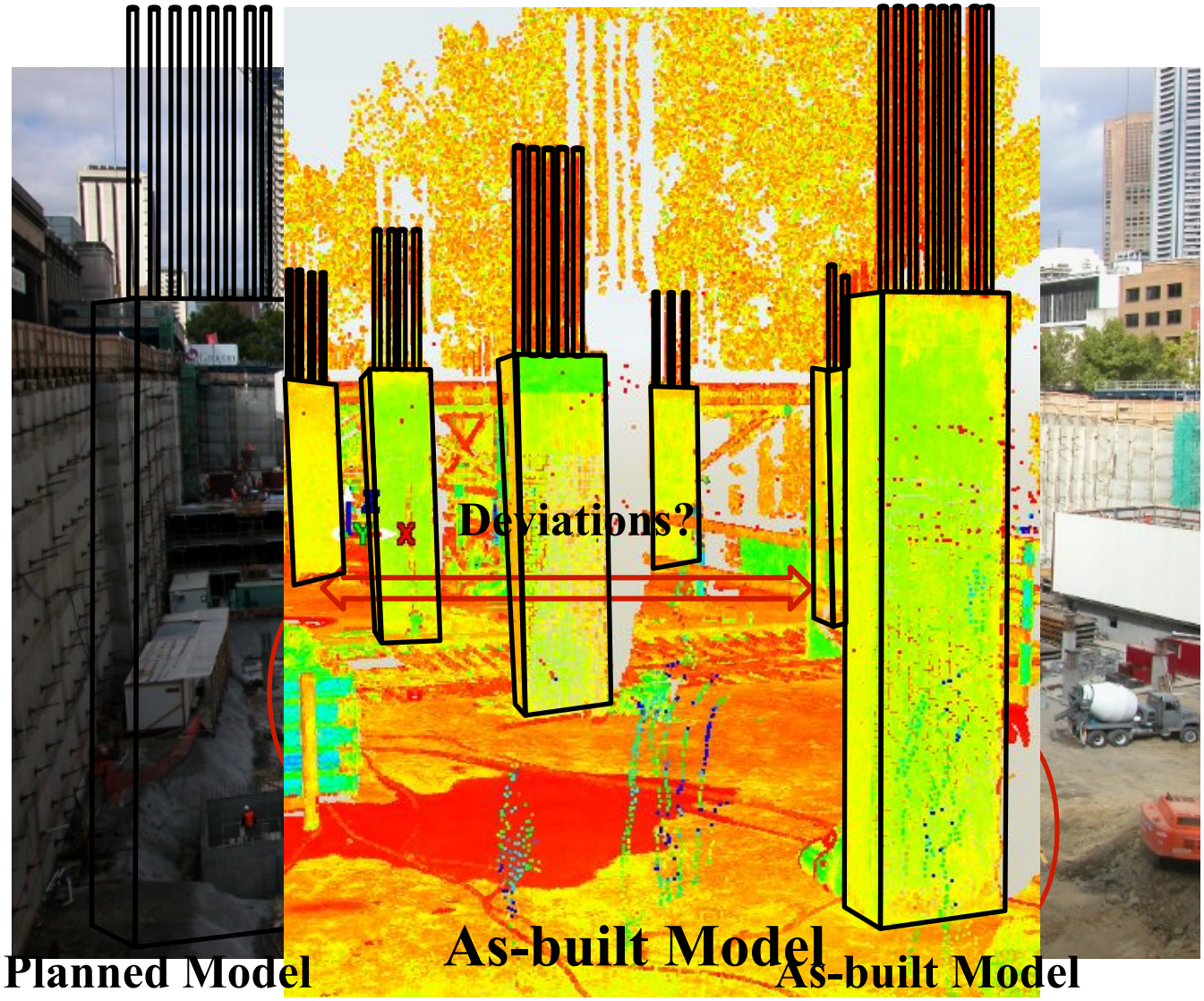
On

Behind

Ahead

Rework

3 Main Questions



Automated As-built Model Generation

Robust PCA

↓

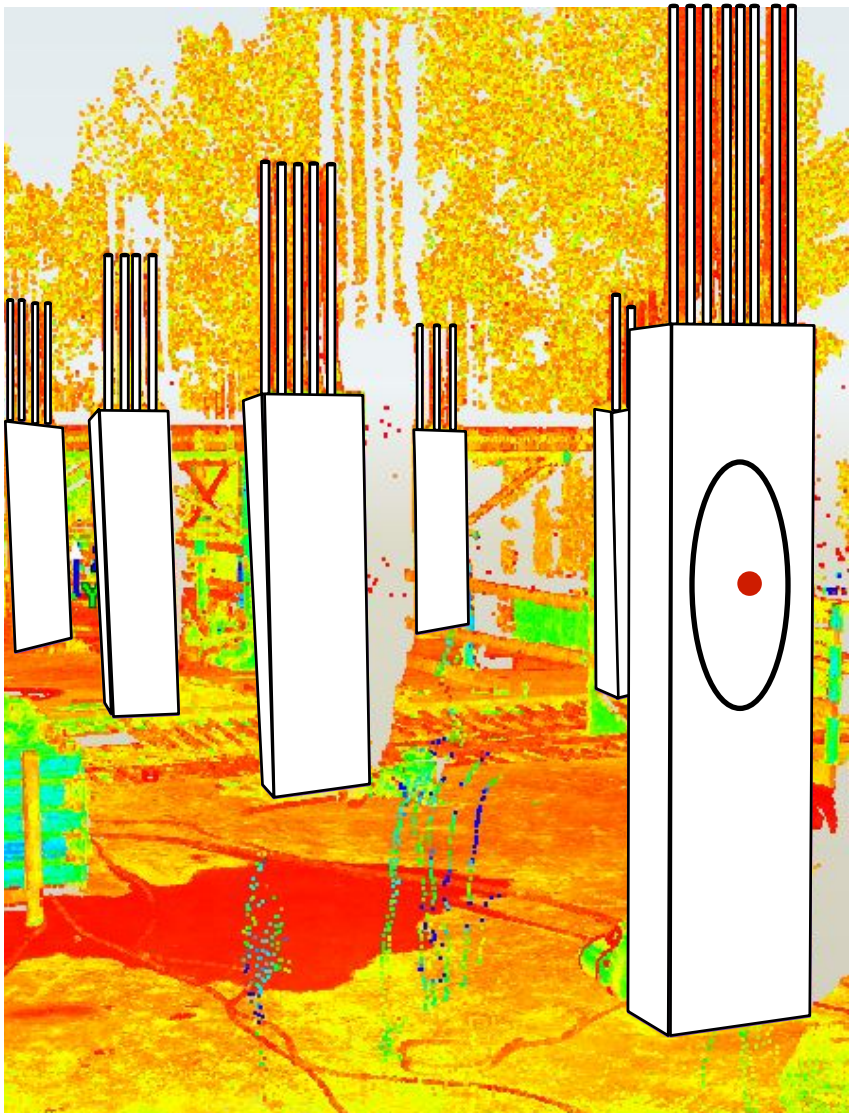
Robust Complete Linkage

↓

Convex Hull

↓

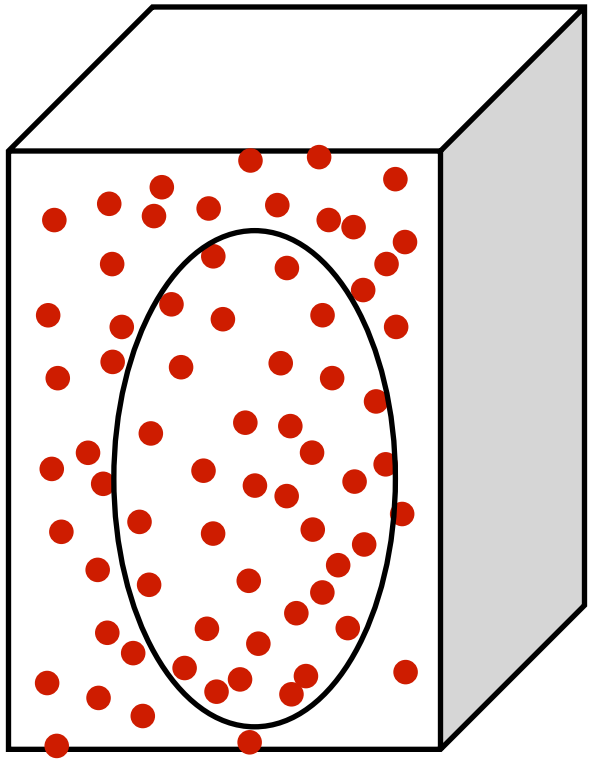
As-built Model

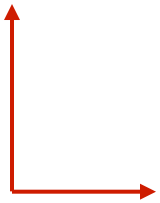


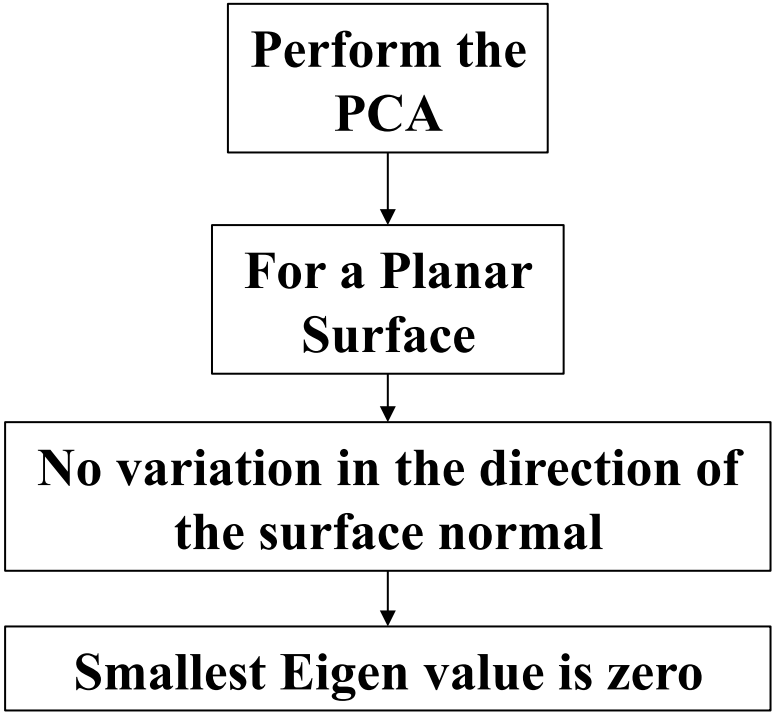
2. As-built Model Generation

a. Point Cloud Classification
b. Point Cloud Segmentation
c. Boundary Detection
d. Data Summarization and Intersection

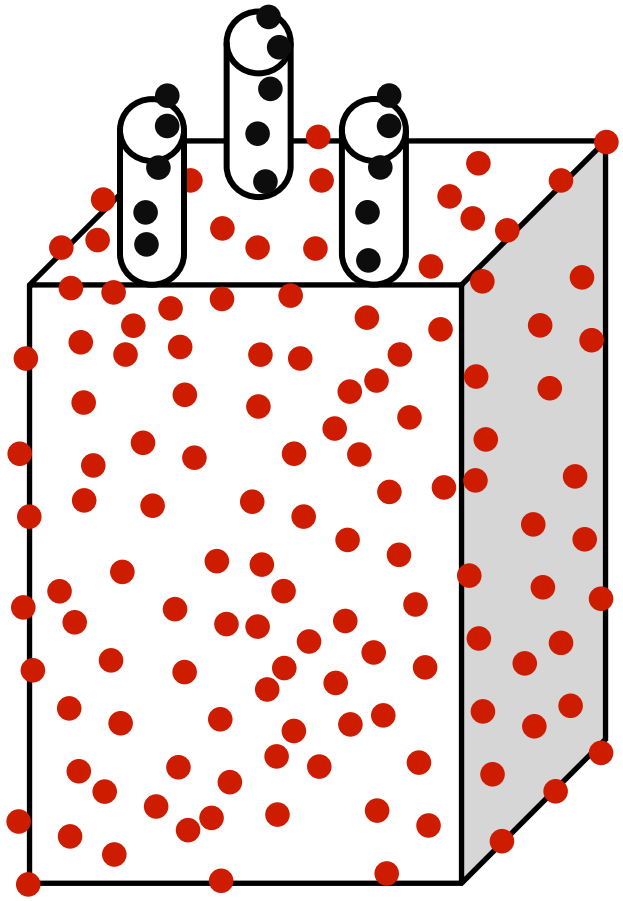
2a. Point Cloud Classification: Planes

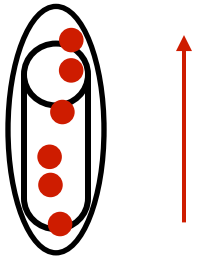






2a. Point Cloud Classification: Lines





Perform the PCA

↓

Majority of the variation in the direction of the longitude

↓

100% of the data in the maximum eigenvalue

Reality

Due to data artifacts caused by:

1. Occlusions
2. Moving objects
3. Dust

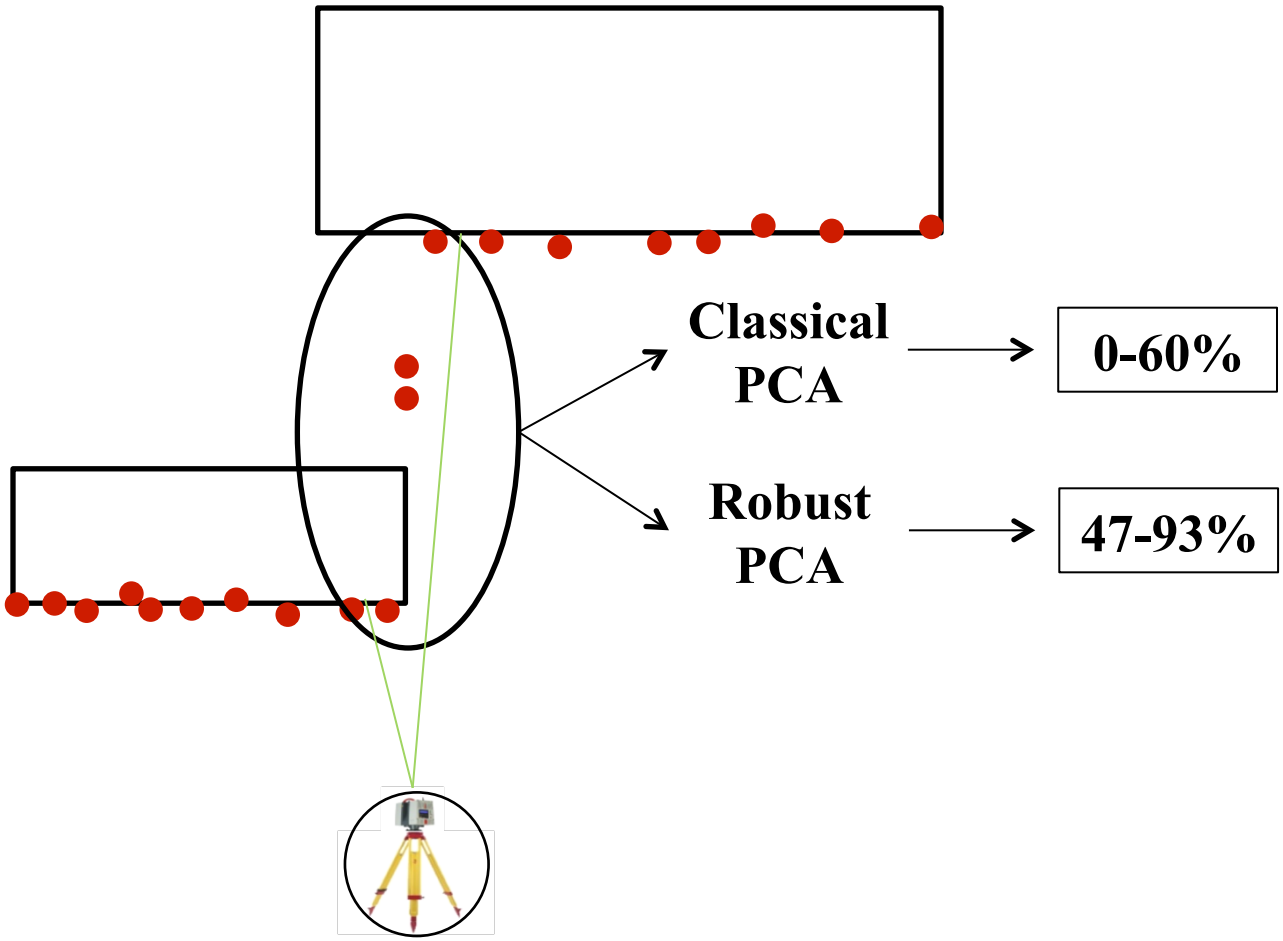
Outliers are present in the data

Classical PCA is very sensitive to outliers [6, 7, 8, 9]

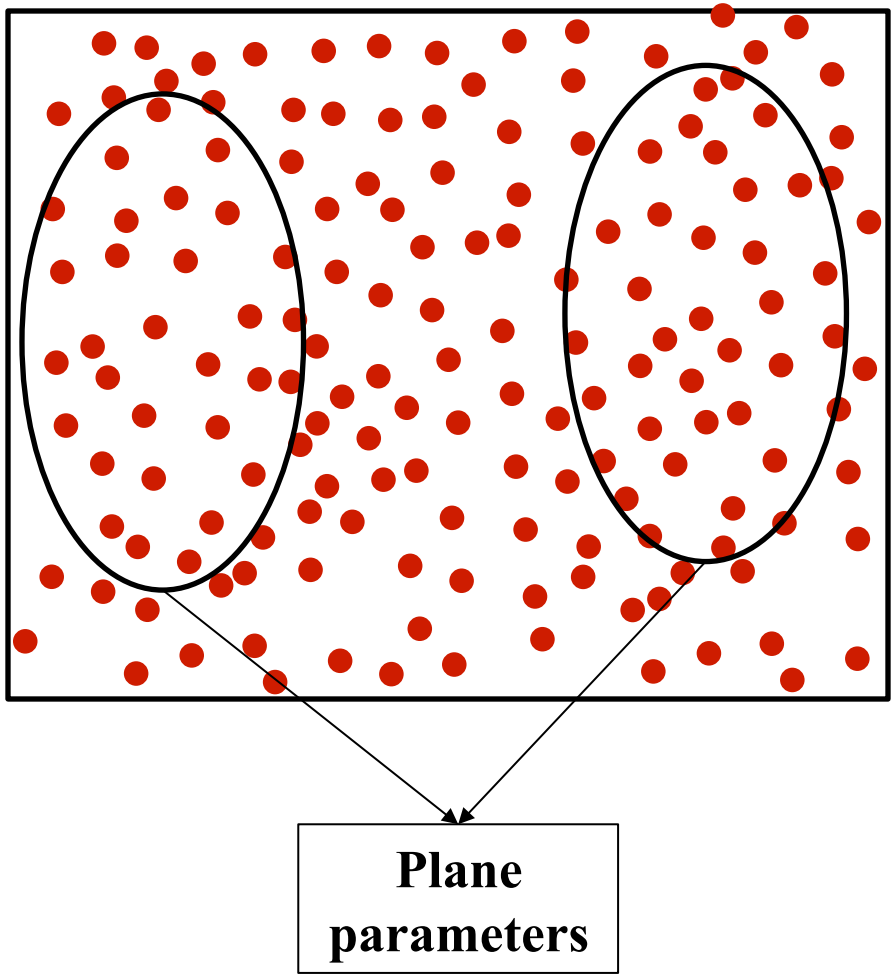
→ Searching for a Covariance estimation Robust to outliers

- Minimum Covariance Determinant (MCD) [8, 9, 10]

Mixed Pixel

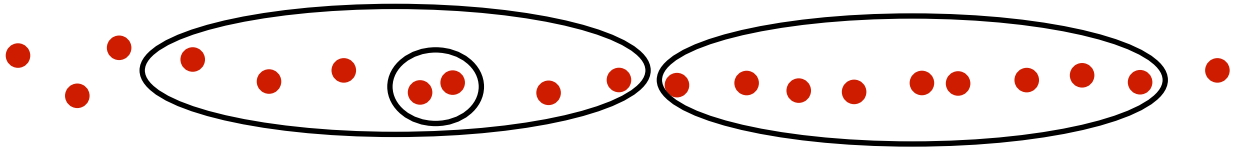


2b. Point Cloud Segmentation



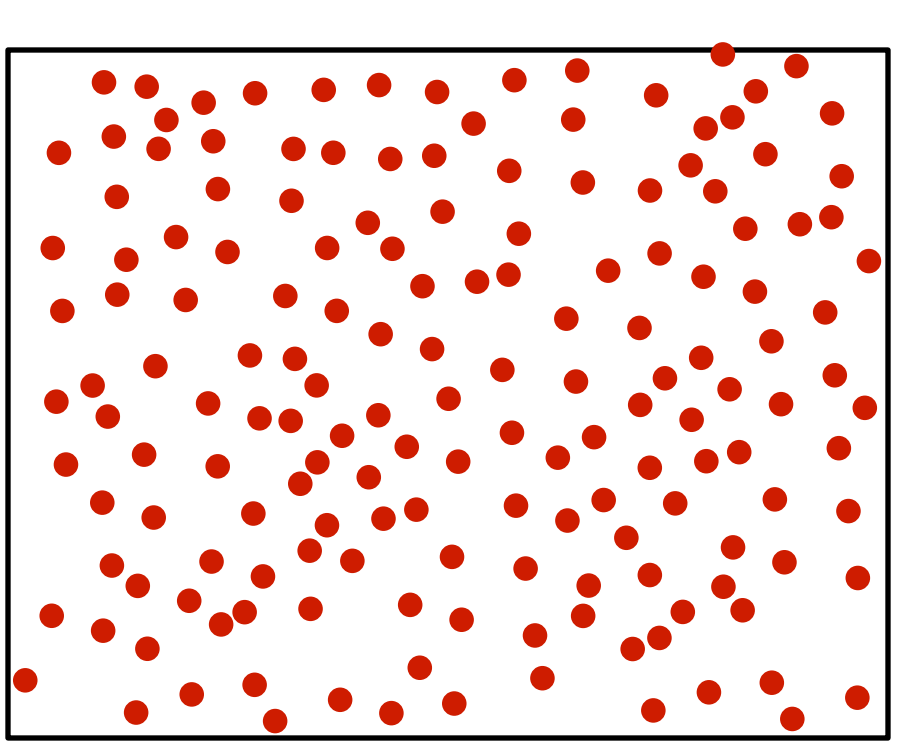
Complete Linkage

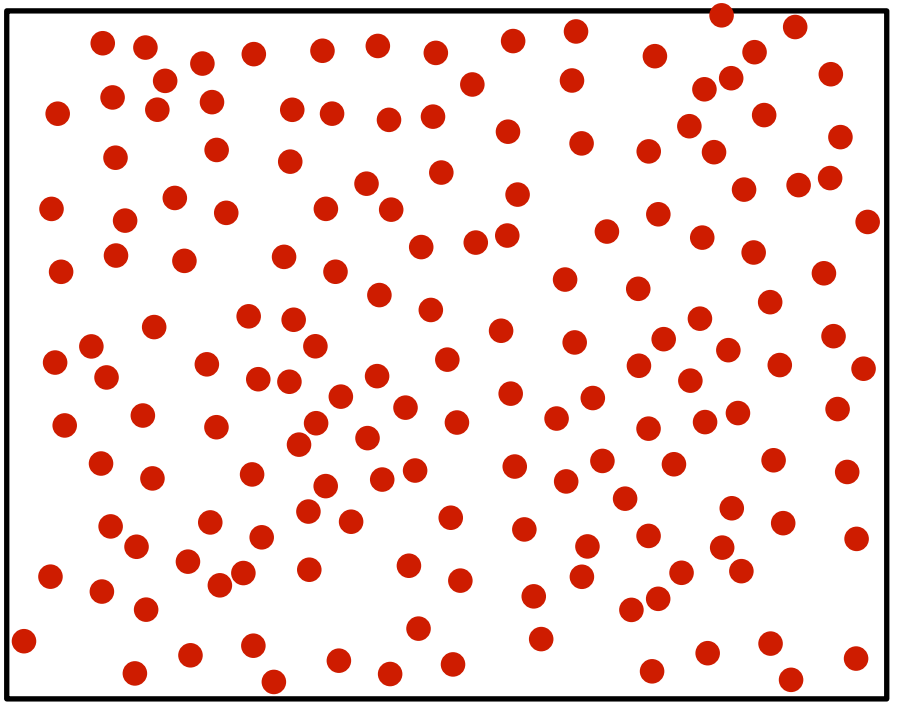
Within the Attribute Space:



No prior knowledge of the number of clusters

2c. Discontinuous Surfaces

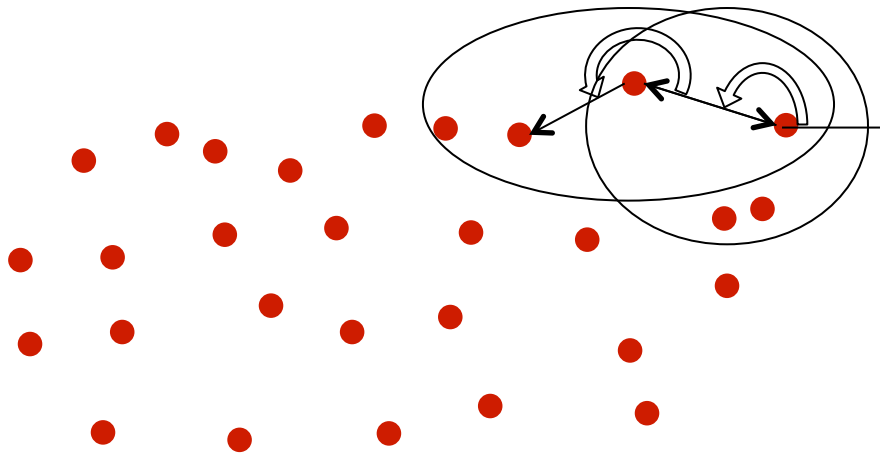




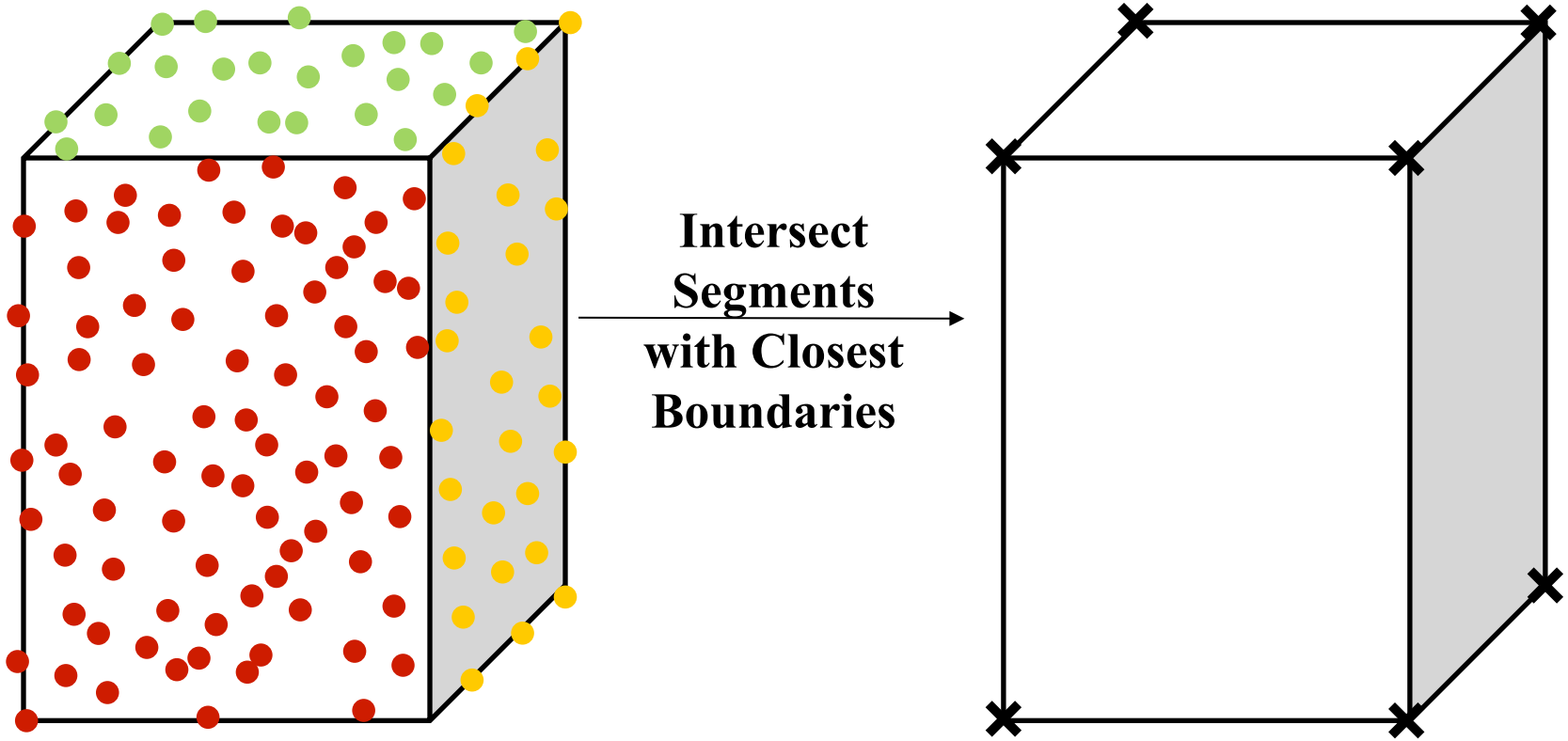
Use the "Modified Convex Hull" algorithm

Boundary Point extraction

Modified Convex Hull algorithm:



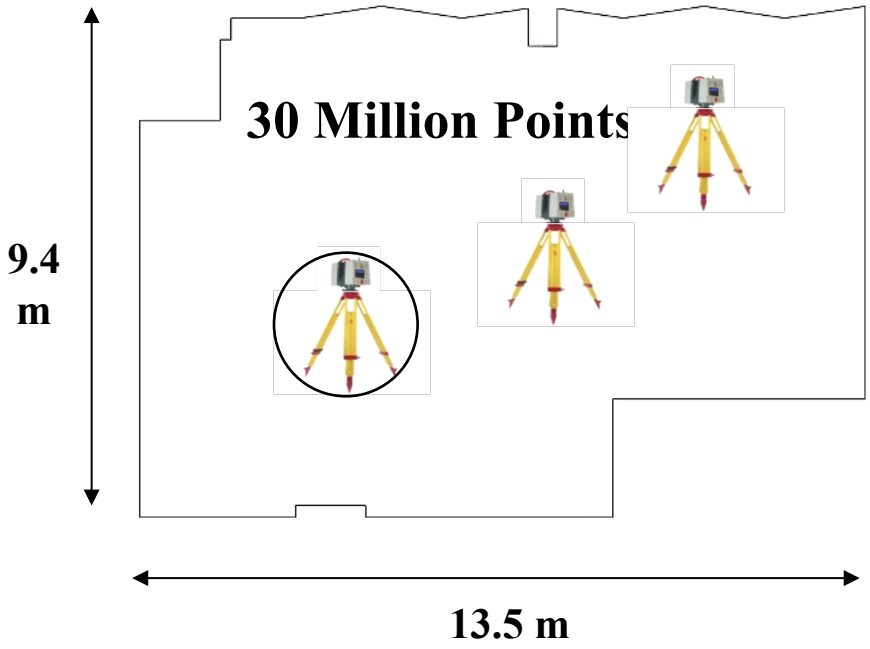
2d. Vertices and Intersection



Experiment 1: Laboratory

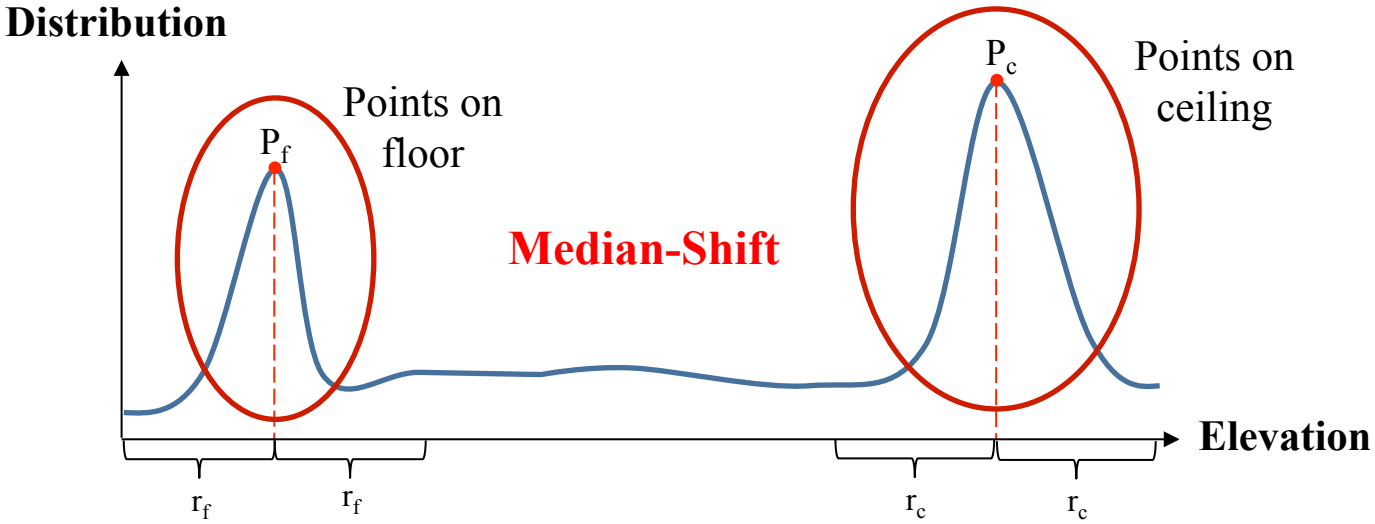
Testing the proposed method in a highly occluded area:

- A set of LiDAR data was collected using Leica HDS6100



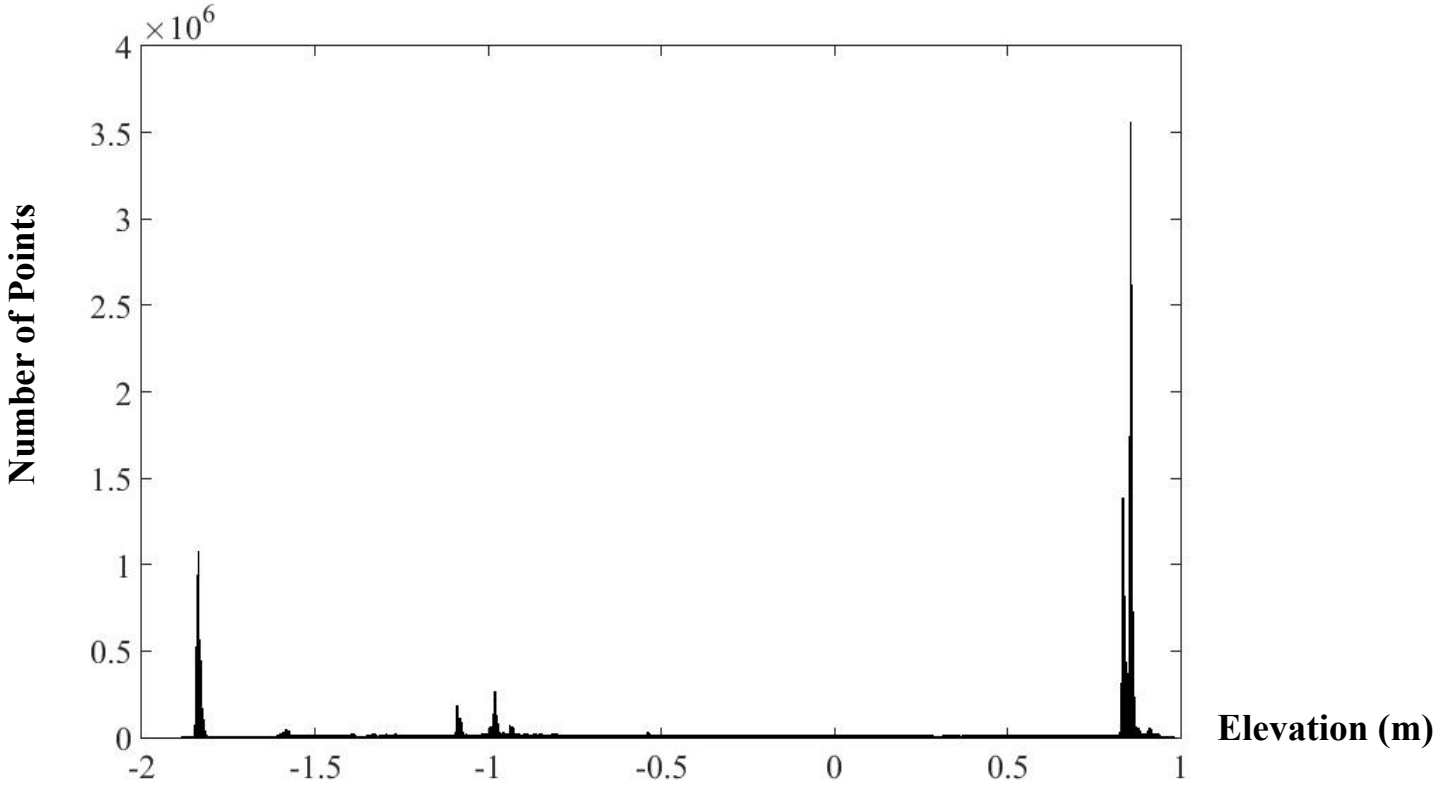
Removing Floor and Flat Slab Ceiling

- To improve Calculation time:



Robust PCA using MCD

Results

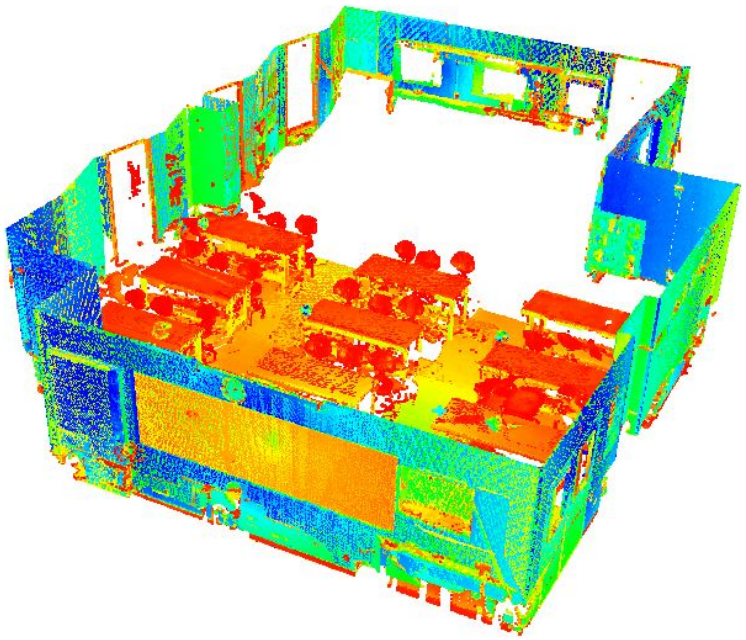


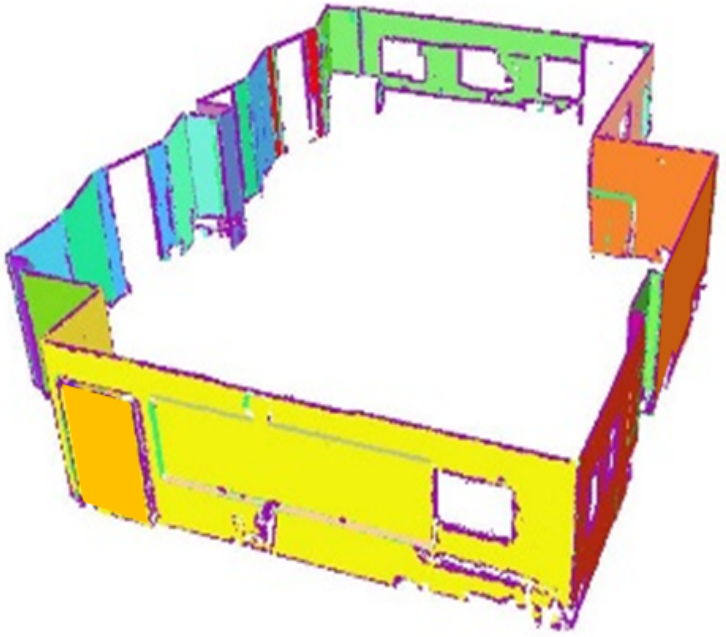
Floor Precision = 91.5%
Ceiling Precision = 92.5%

Recall=100%

Accounting for more than half of the points

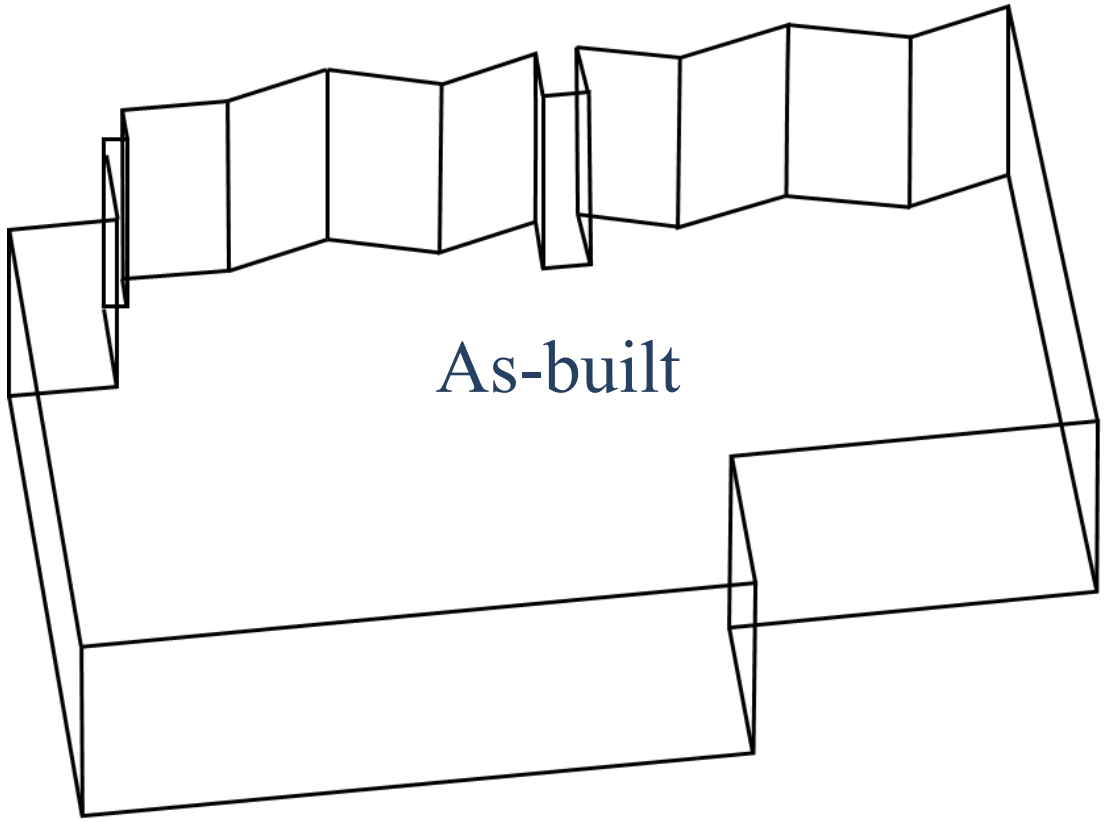
Experiment 1: Robust Segmentation



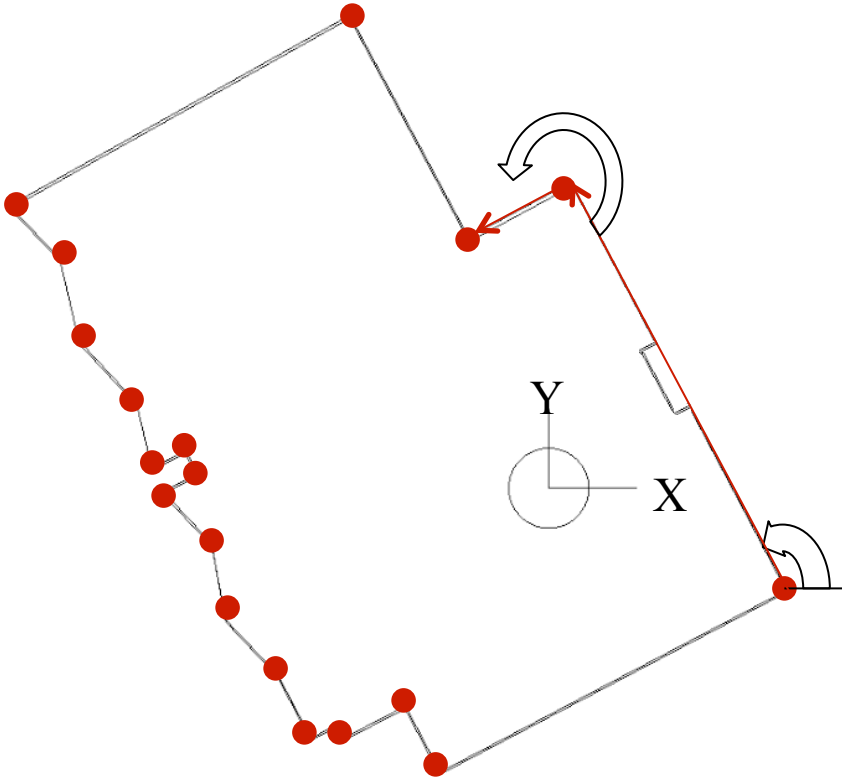


95% of the points correctly segmented → **30% improvement to current available method**

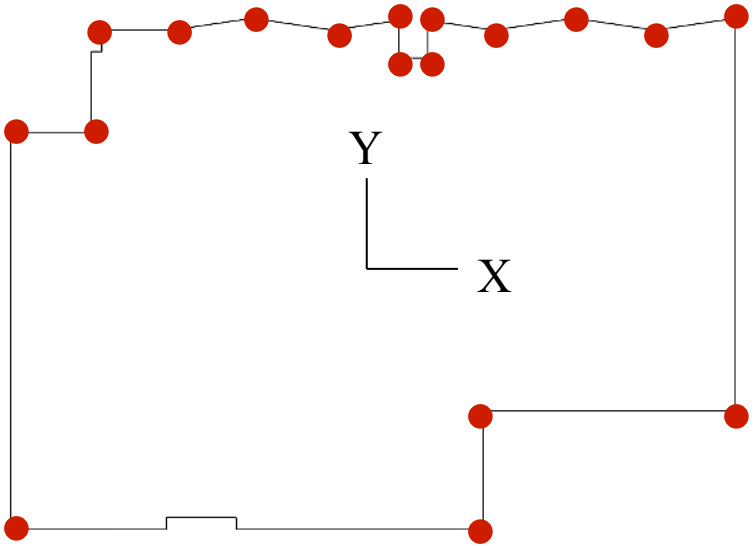
Experiment 1: As-built Model



Registration?

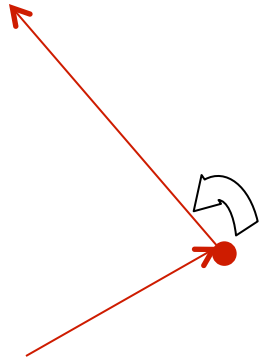


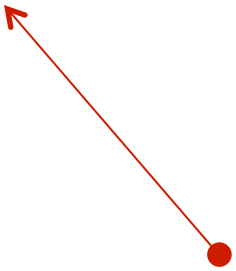
As-built Model

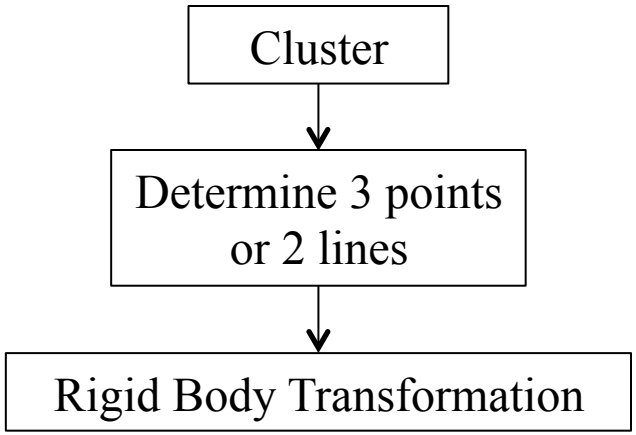


As-planned Model

2 Metrics for every point



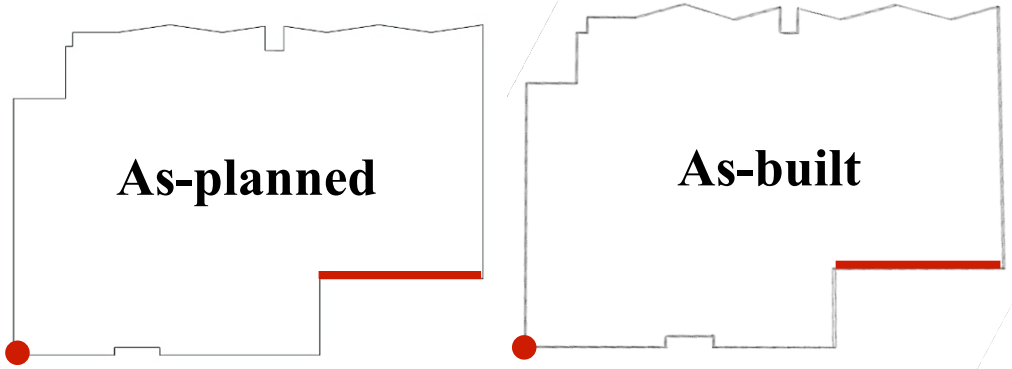




Experiment 1: Results

Accuracy Assessment:

XRSE = 7cm
YRSE = 6cm
ZRSE = 1.2cm
MRSE = 9.4cm



Dimension Compliance Control of Walls:

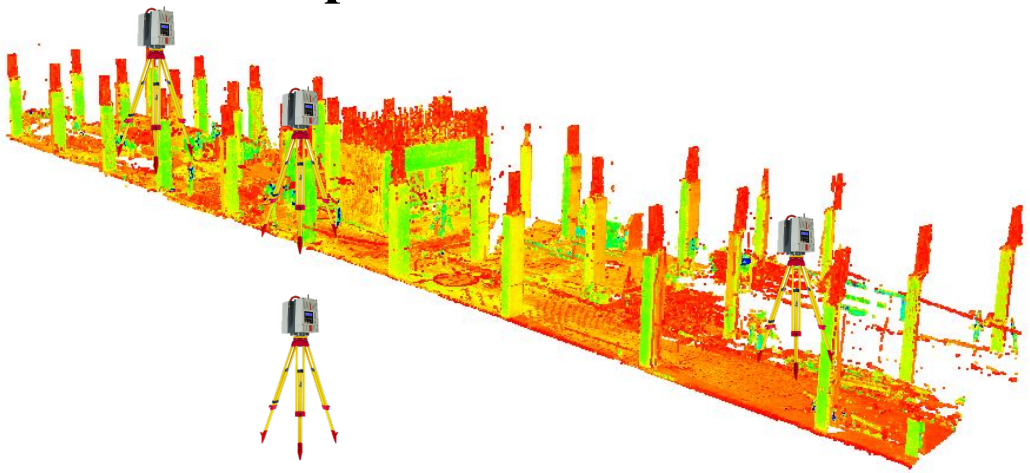
Horizontal Direction = 7.5cm
Vertical Direction = 2.4cm

As-built vs. Total-station → **MRSE** = 0.7 cm → **9.4 cm is the errors during construction**

Experiment 2: Construction Site

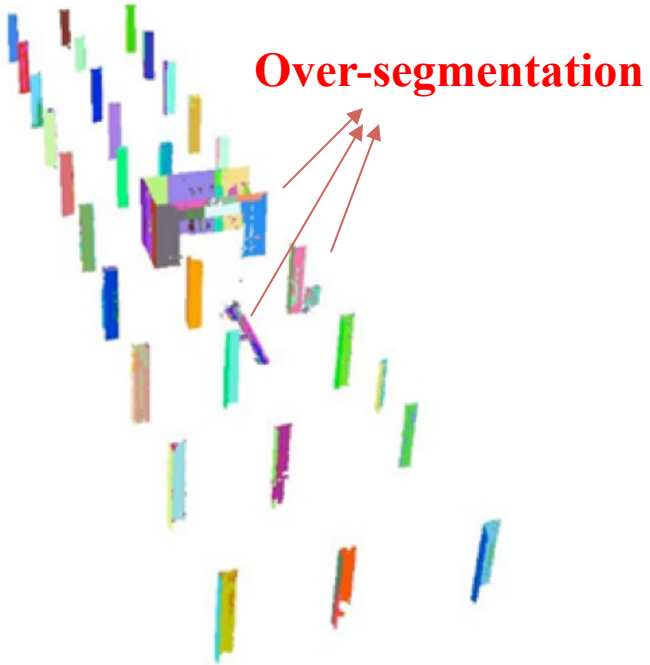
Graduate Student Hall of Residence Project:

150 million points from 4 scan-stations



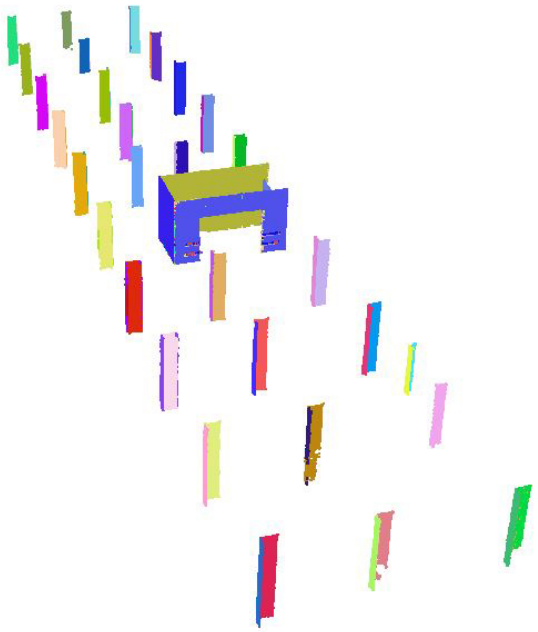
Experiment 2: Robust Planar Segmentation

Using Region Growing and Classical PCA



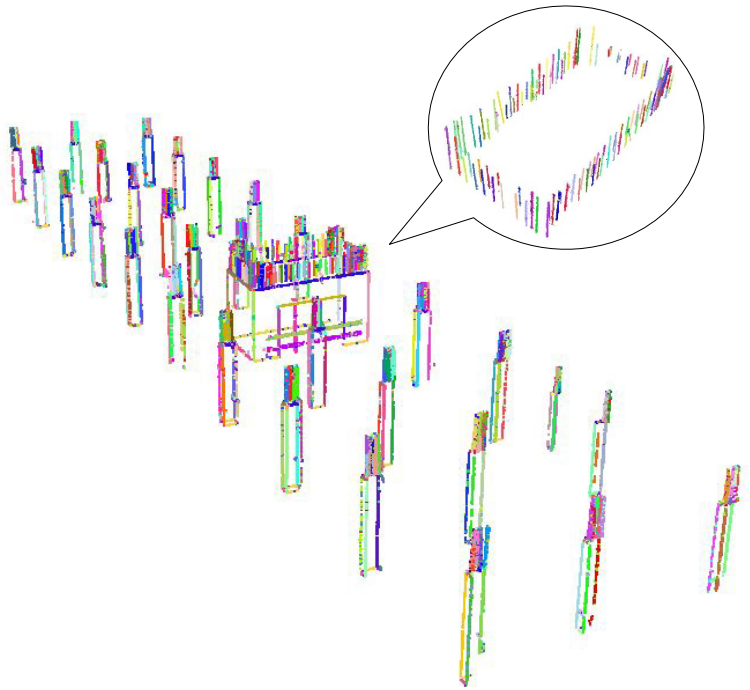
Planar Segmentation: 73% Accuracy

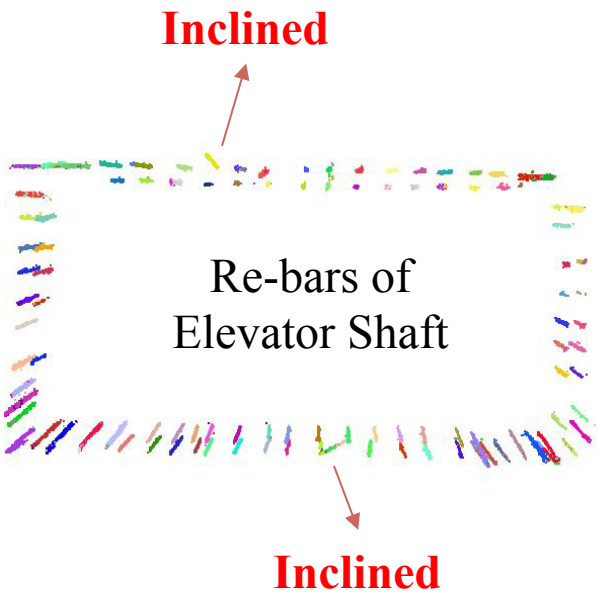
Using Our Robust Method



Planar Segmentation: 95.2% Accuracy

Experiment 2: Robust Linear Segmentation

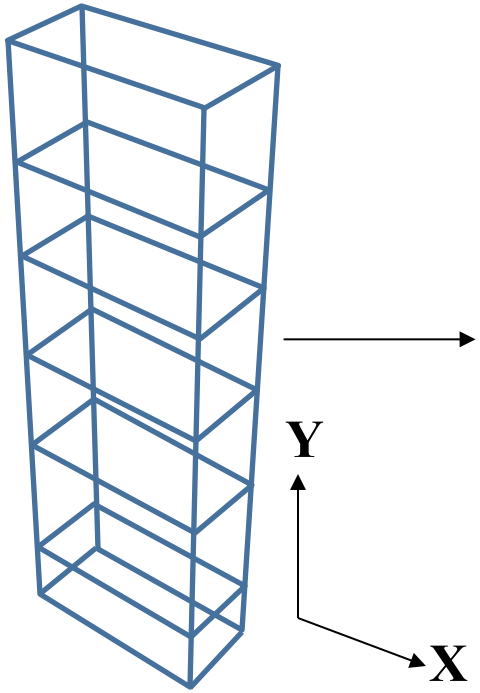




Linear Segmentation:
91.4% Accuracy

Experiment 2: As-built modelling of Elevator shaft

As-built

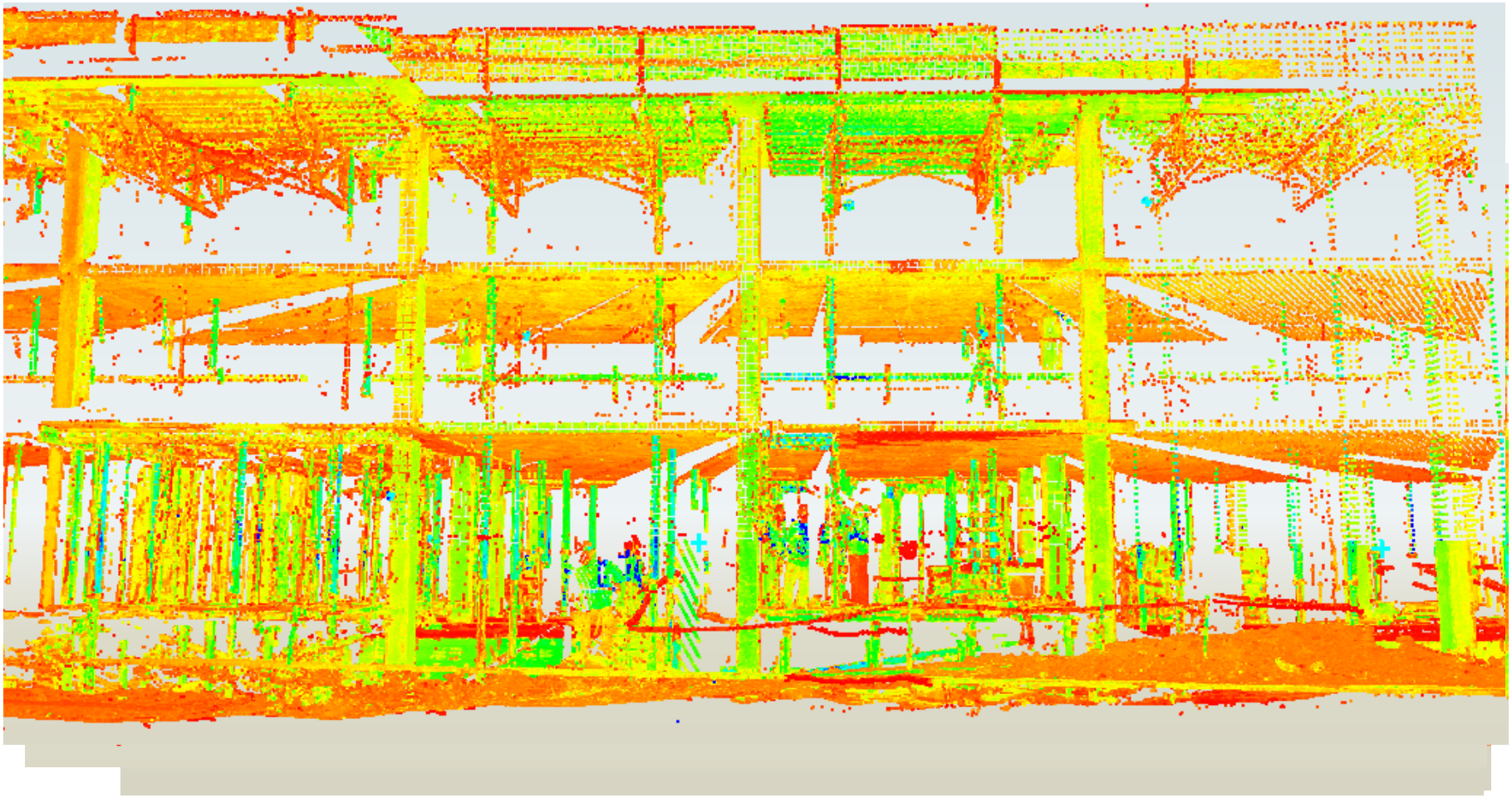


Dimension Compliance:
±1.4 cm in X
±1.6 cm in Y

Contractor suggested tolerance of ±2 cm

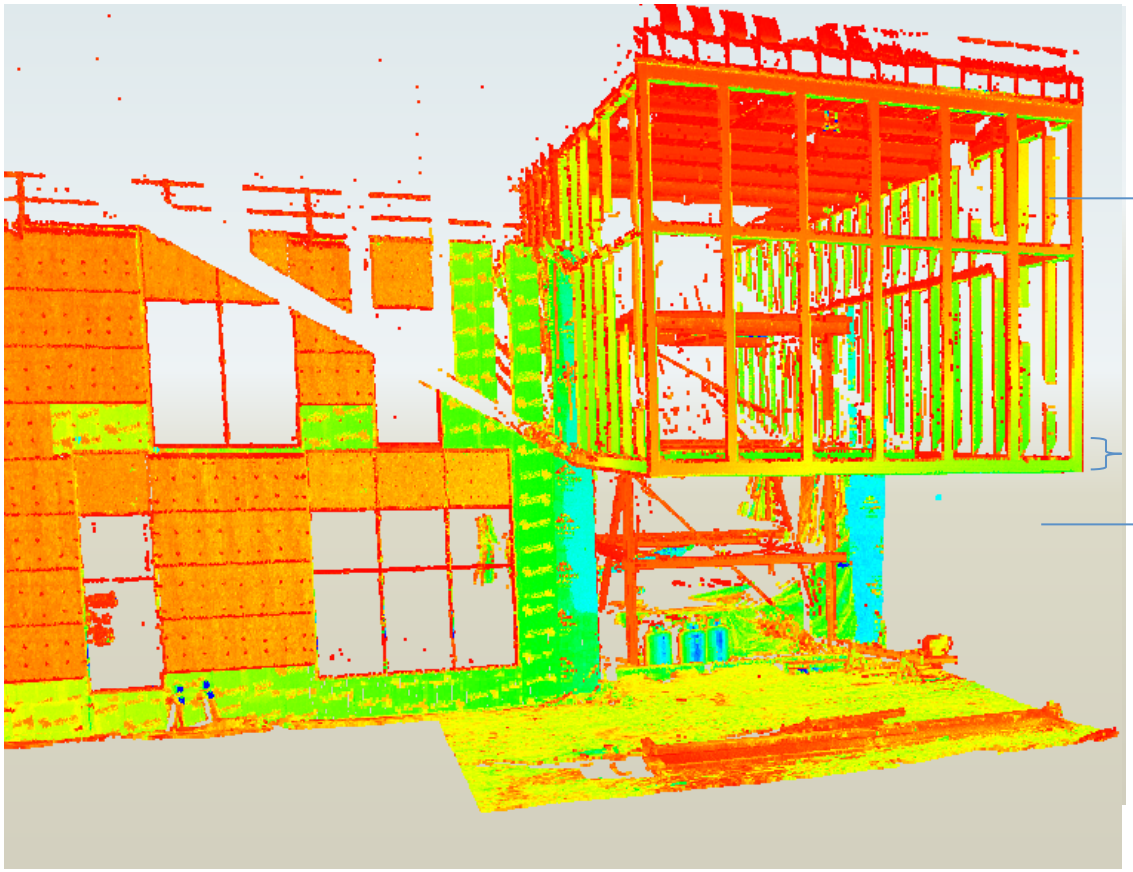
Future Work: Progress Monitoring

Graduate Student Hall of Residence Project:



Future Work: Dimension Compliance

Taylor Institute of Teaching and Learning Project:



Contributions

- Fully Automated Monitoring and Control Process
- Automated As-built Model Generation Process
- Novel Robust Planar and Linear Classification Method
- Novel Robust Planar and Linear Segmentation Method

Construction Industry benefits:

- Reducing monitoring time, cost and quality
- Reducing rework due to poor quality
- Reducing construction claims and disputes
- Quality assurance, and dimension compliance control

Thank You for Your Attention

Questions?

References

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