Acquire, Visualize, and Analyze Building Models for Construction Progress Monitoring

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Final: Master Informatics

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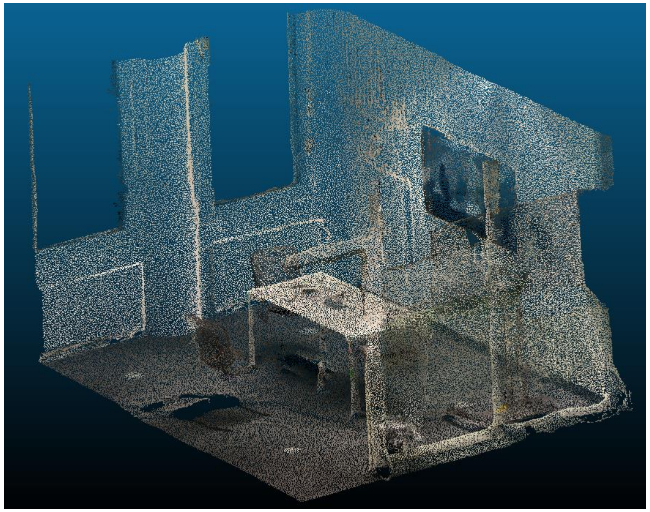
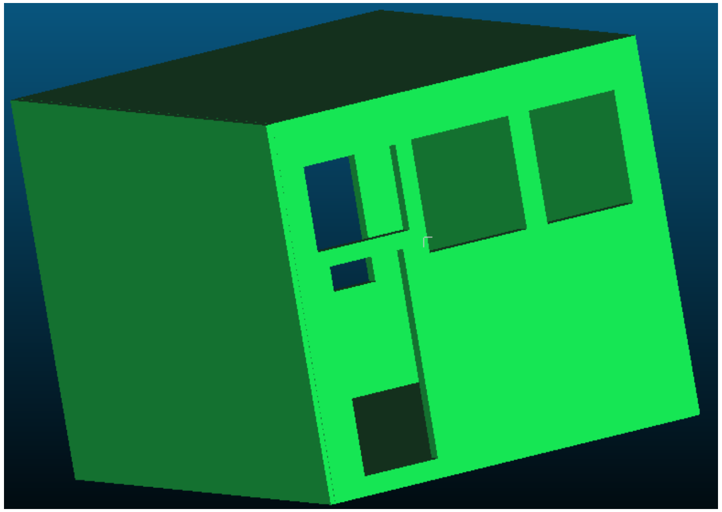
In collaboration with Siemens AG

Motivation

- Monitor **construction state**
- Compare **as-built** state with **as-planned** state
- **Detect deviations** between scan and model
- **Detect errors** at an **early** stage



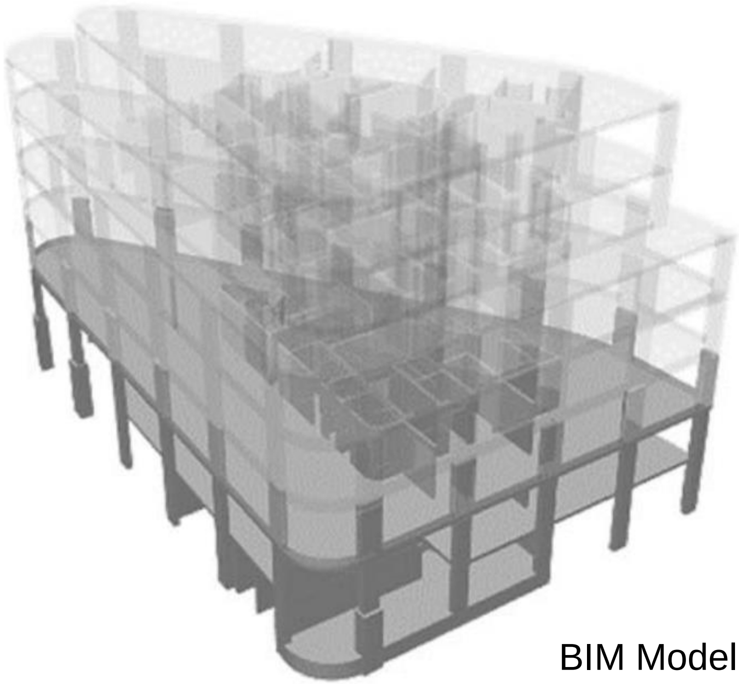
Point Cloud Scan (Office Fragment)



CAD Model of Office

Problem Description – Issues

- **Scale**: Construction areas are often very large
- **Time-consuming** to monitor work progress
- **Missed errors** during construction by manual monitoring



BIM Model and Construction Site [1]

Building Information Modeling (BIM)

- **Plan** modern **buildings**
- **Show** and **add information** to projects

- Only 3D software (3D BIM)
- **Schedules** and **construction activities** (4D BIM)
- Construction **cost** development (5D BIM)

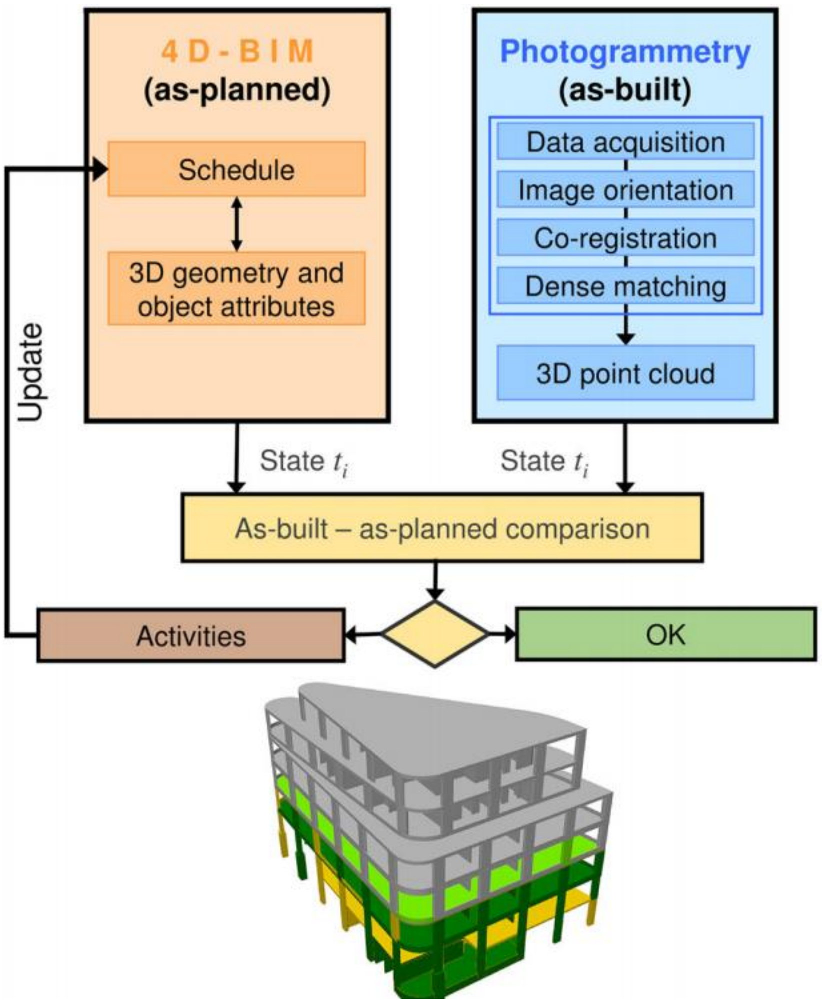
- Usually saved as Industry Foundation Classes (**IFC**) [2]

Logo of buildingSMART [2]

Related Work

- **Photogrammetric** surveys
- **BIM** model data
- Compare **schedule** and **built time**
- **Highlight components**

Borrmann et al. [1, 3]



Construction Monitoring with 4D Model and Point Cloud [1]

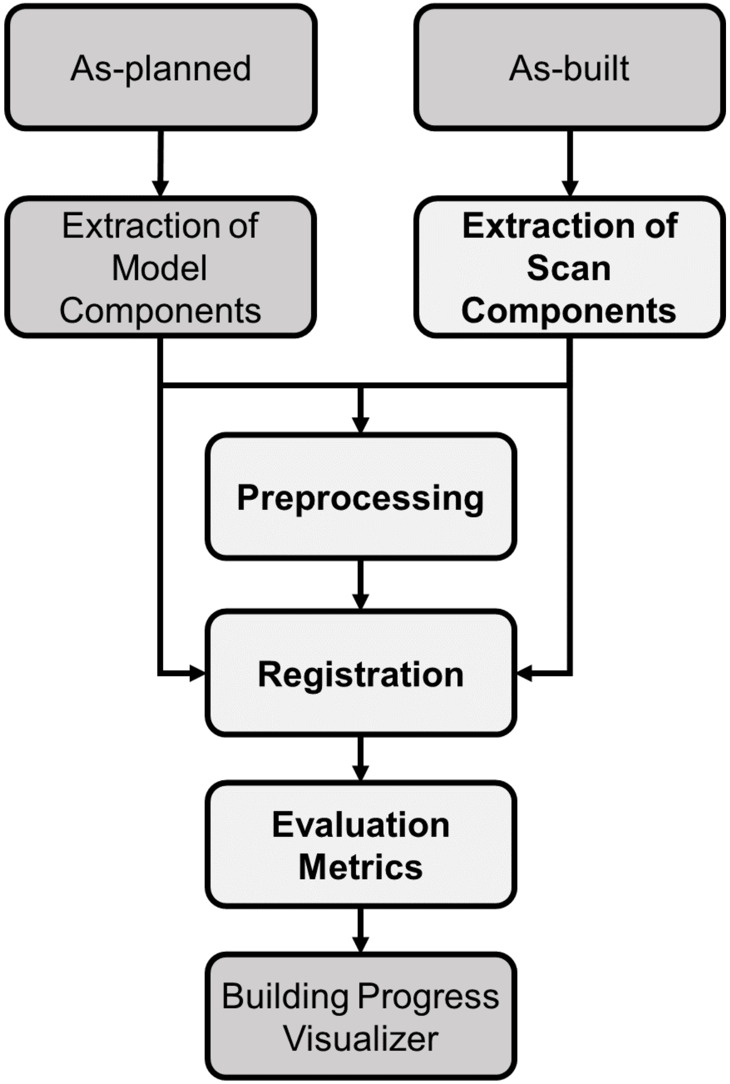
Goals of this Thesis

- **As-built vs. as-planned** comparison
- **Verify** that planned **structural elements** are correctly built

- **Identify** and **extract elements** in scan and model
- **Align** scan and model point clouds (Registration)
- **Evaluate** and **Visualize** results

Approach

- **Research** for algorithms
- **Prototype**
- **Evaluate** sample datasets



Architecture of the Prototype

Implementation – Datasets

- Apple hand-held **LiDAR** sensor data
- S3DIS scan
- **Laser Scans** and **Photogrammetric** data
- Datasets:
  - Model: IFC Models
  - Scan: Point Clouds
  - A) Unclean B) Clean
  - C) Scaled D) Unscaled

LiDAR Office Scan

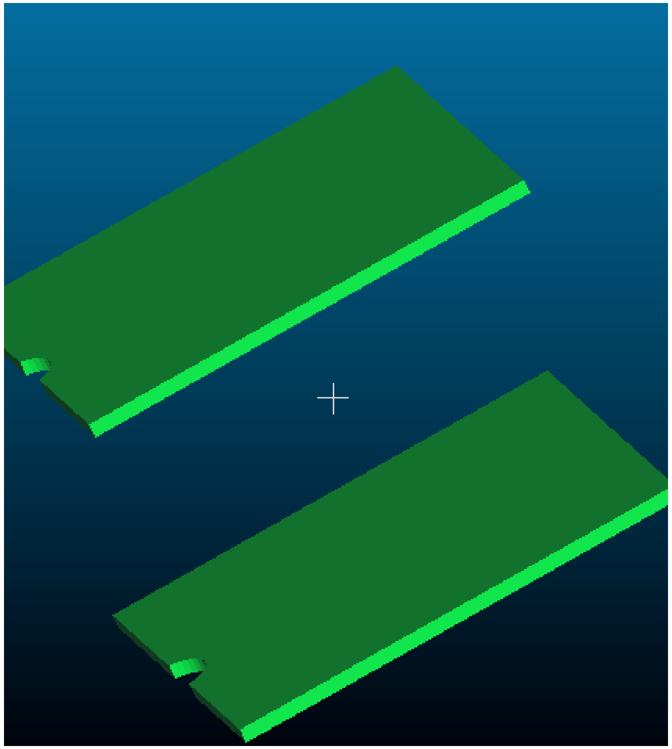
Construction Site Scan [3]

Implementation – Extraction of Model Components

- Input: IFC file

1. Choose **IFC element type** to be **extracted**
2. Convert elements to **vertices** and **faces**
3. Save elements as **mesh**

- Output: IFC elements as mesh



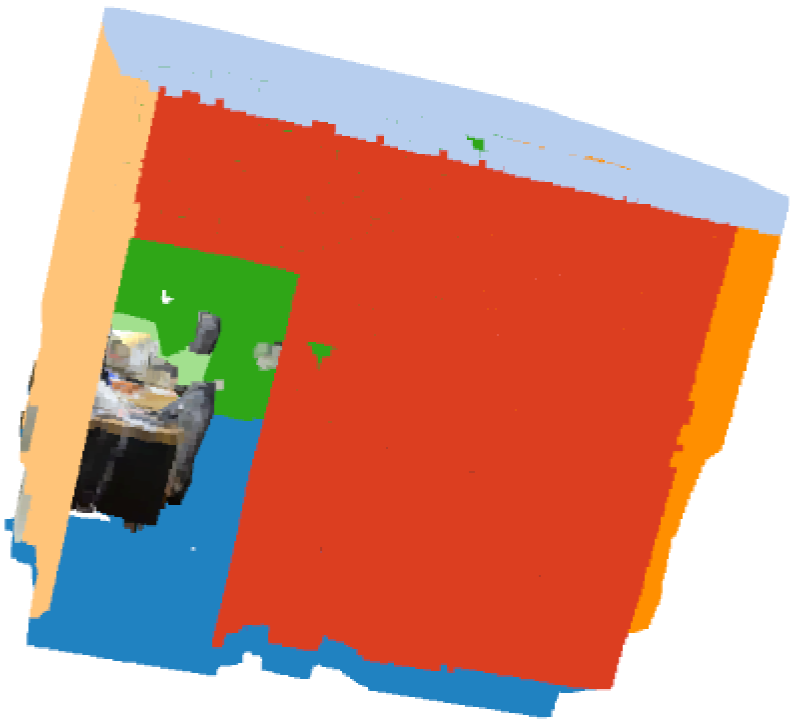
Extracted IFC Slabs as Mesh

Implementation – Extraction of Scan Components

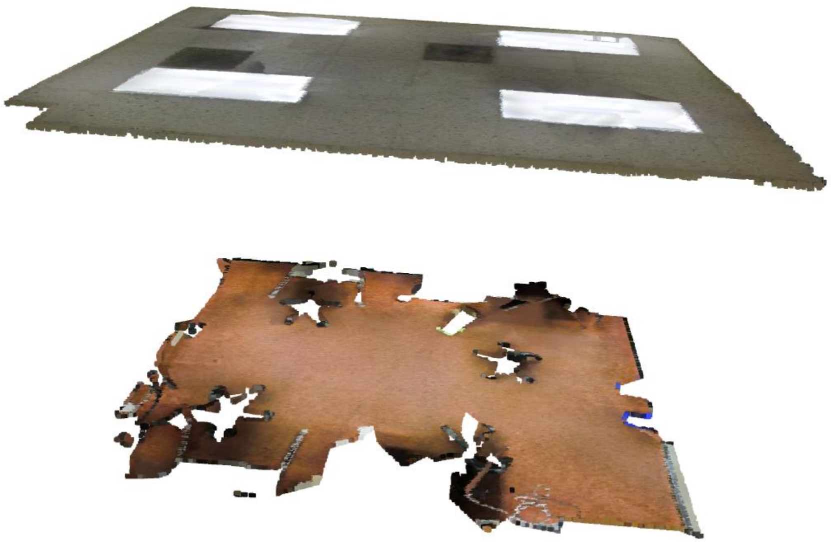
- Semantic Segmentation:
  - **Detects** and **labels unknown** objects **automatically**
  - Model Architecture: RandLA-Net [5]
  - Dataset: S3DIS [4]

- Plane Segmentation:
  - **Detects largest contiguous** planes of point clouds
  - RANSAC [6]
  - DBSCAN [7]
  - **Manual** assignment of segmented objects

Implementation – Extraction of Scan Components



Colorized Plane Segmentation



Semantic segmentation of Ceiling and Floor as Mesh

Implementation – Preprocessing

Loading Models → **Voxel Downsampling** → **Noise Filtration and Outlier Removal**

Key Point Detection → **Normal Computation** → **Feature Information Extraction**

Implementation – Registration

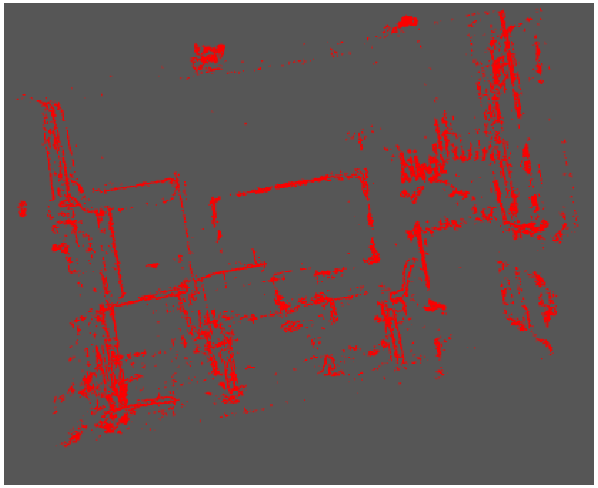
- **Aligning** two point clouds via **transformations**

- **Coarse/Global** Registration
- Initialization and rough alignment of point clouds
- Used algorithms:
  - Fast Global Registration [8] (correctly scaled)
  - Coherent Point Drift (CPD) [9] (not correctly scaled)

Implementation – Registration

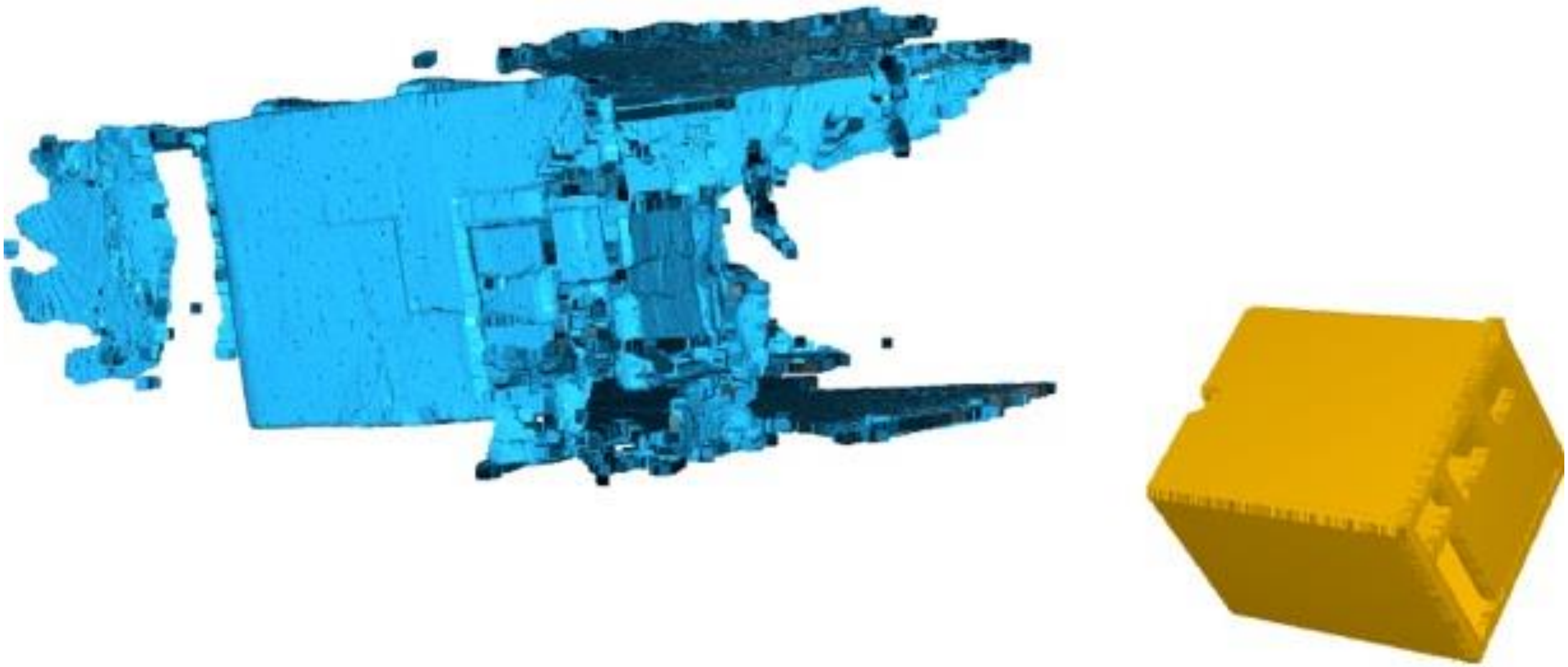
- **Local** Registration (ICP) [10] on **Original** Point Cloud Data
- **Local** Registration (ICP) [10] on **Edges** of Point Cloud Data
  - Surface Reconstruction
  - Edge Extraction

Reconstruction of a Point Cloud as a Mesh



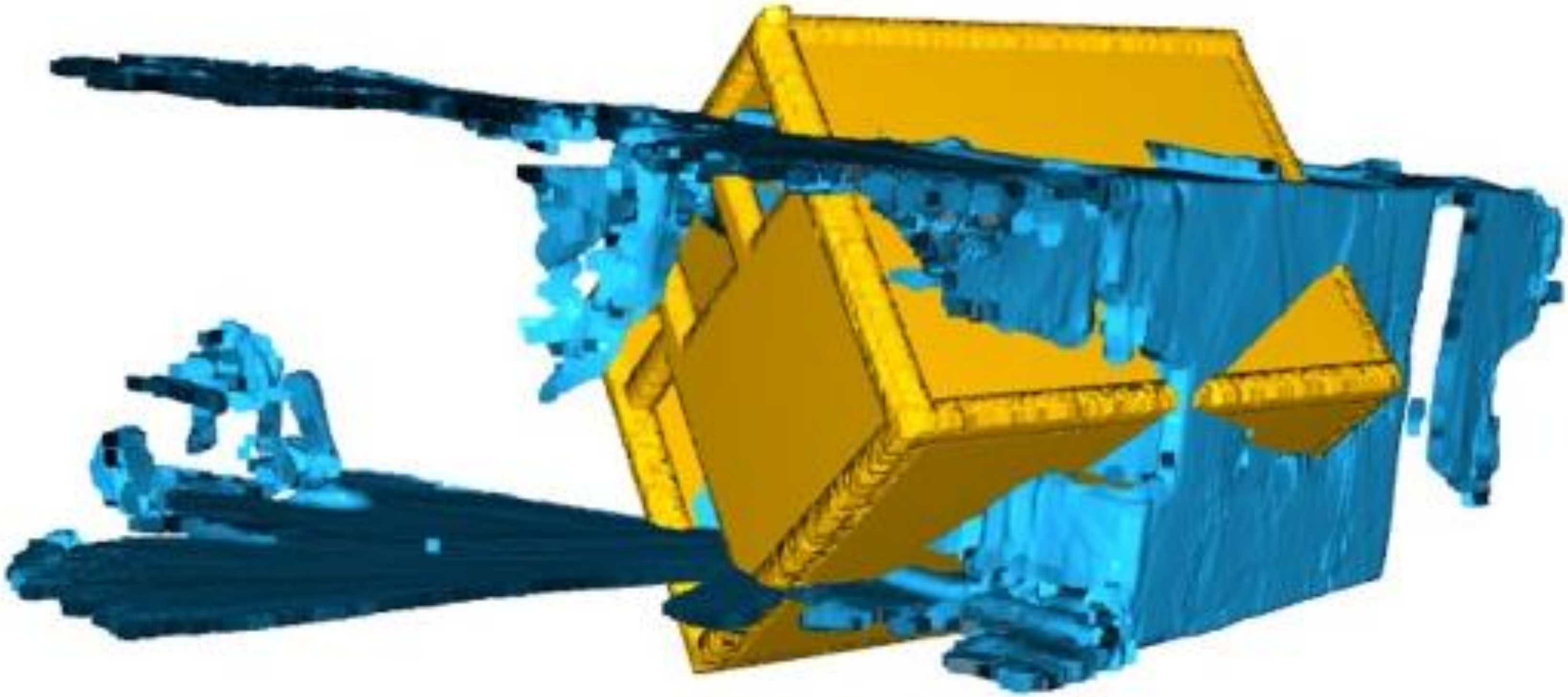
Extracted Edges of the Point Cloud

Implementation – Start Registration



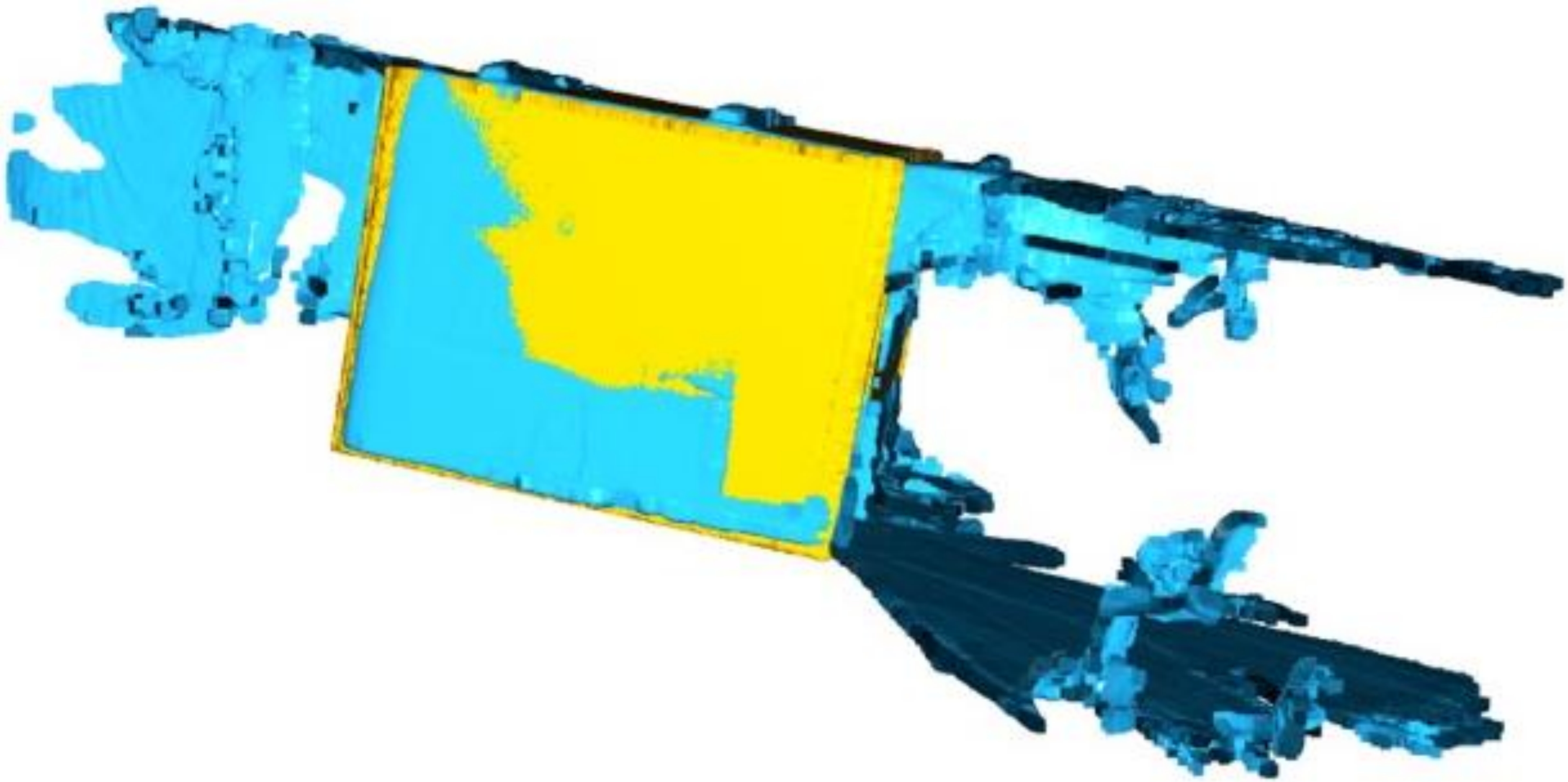
Model and Scan before Registration

Implementation – Global Registration



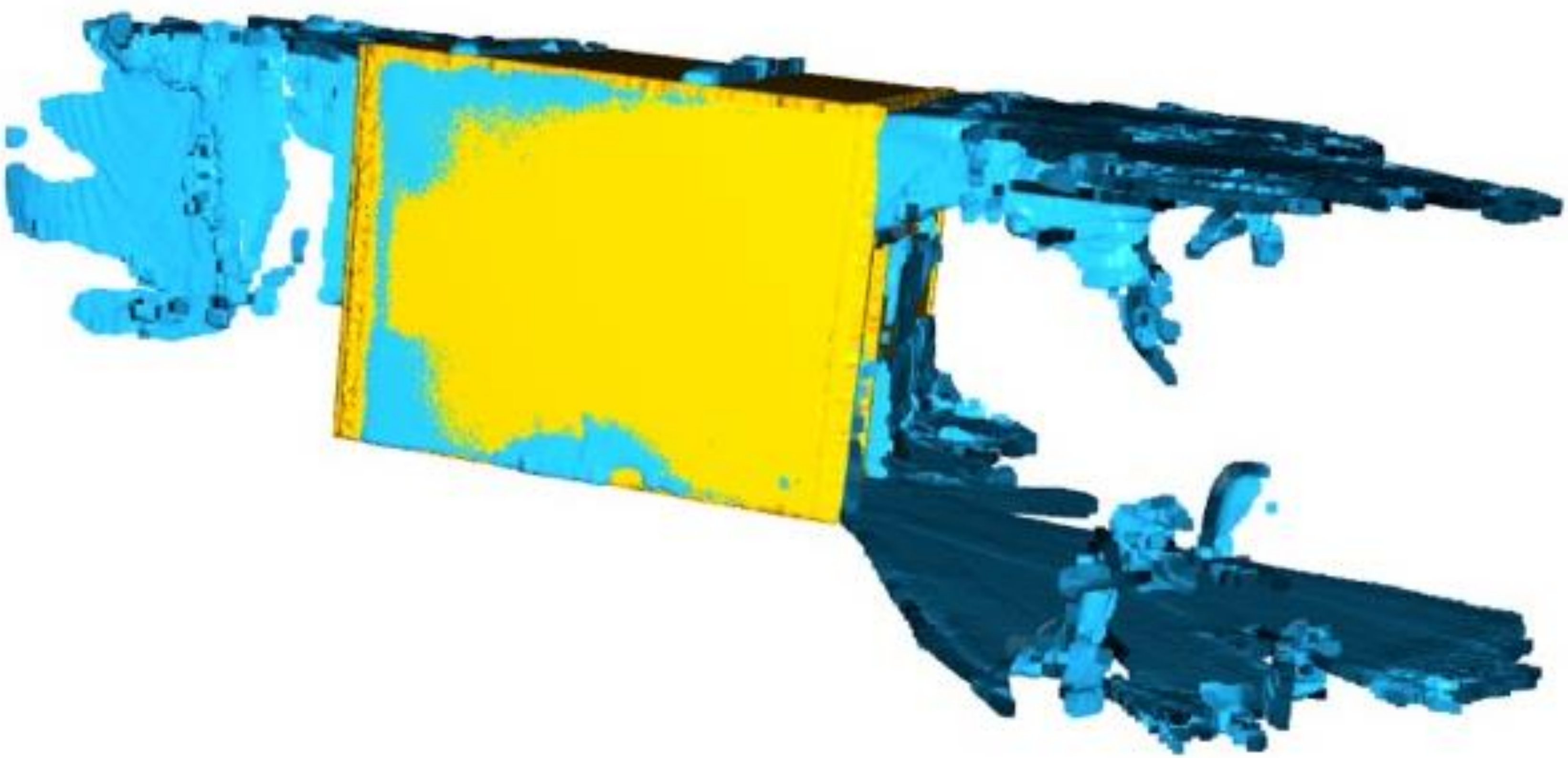
Registration Result after Global Registration

Implementation – First ICP



Registration Result after First ICP (Original)

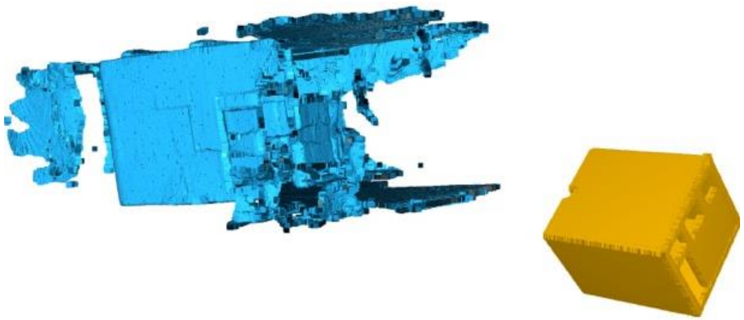
Implementation – Second ICP



Registration Result after First ICP (Edges)

Implementation – Overview of the Steps

1.



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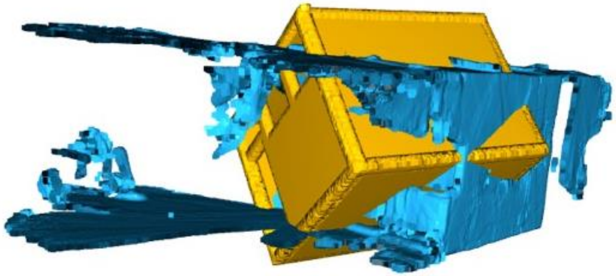
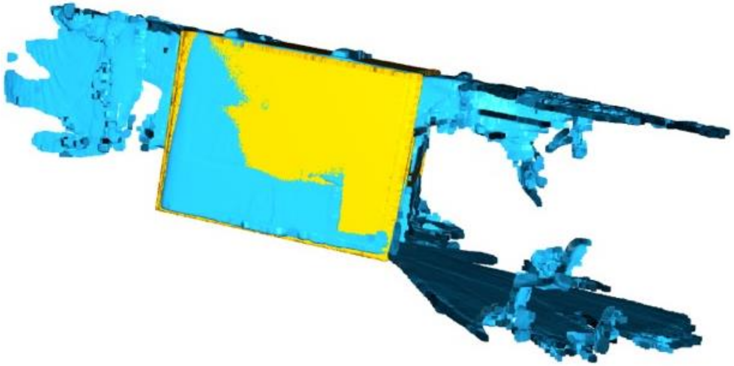
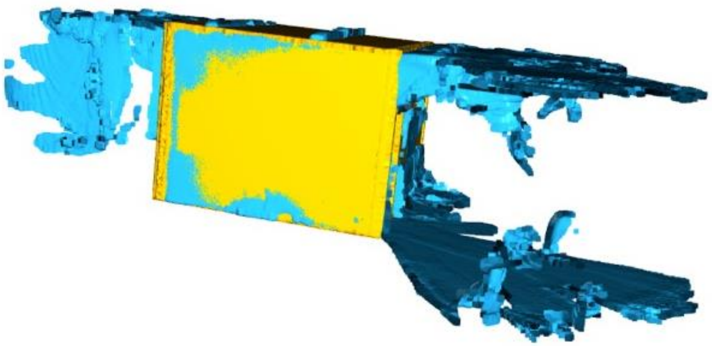


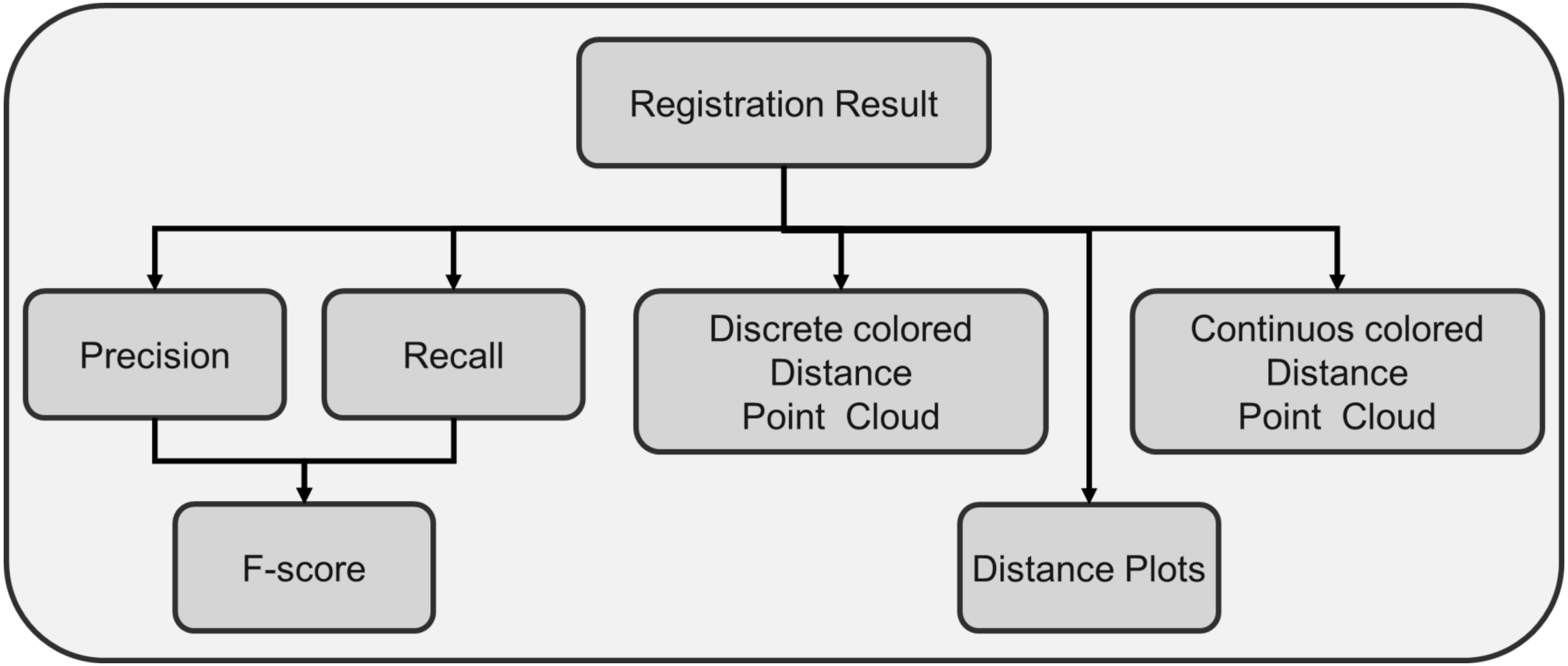
3.



4.

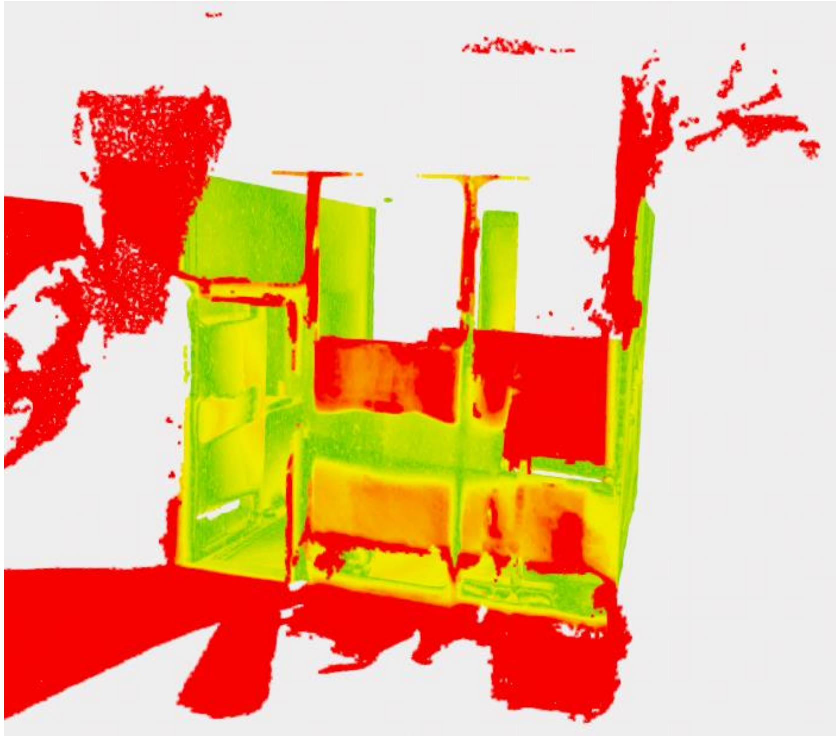


Implementation - Evaluation Metrics



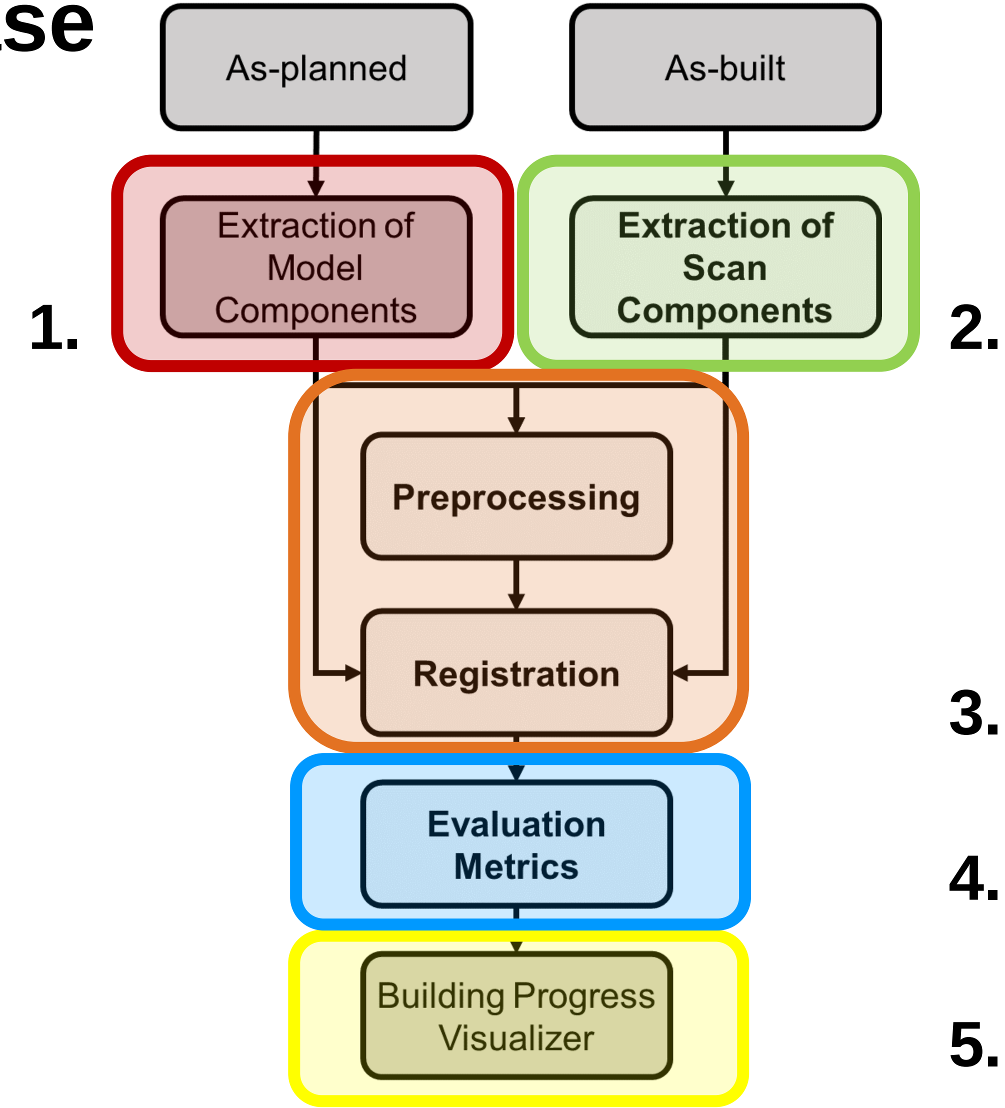
Implementation - Building Progress Visualization

- Visualize **multiple state** comparisons
- Animate building progress
- Filter deviations:
  - **Match** (green)
  - **Small Mismatch** (yellow)
  - **Big Mismatch** (red)

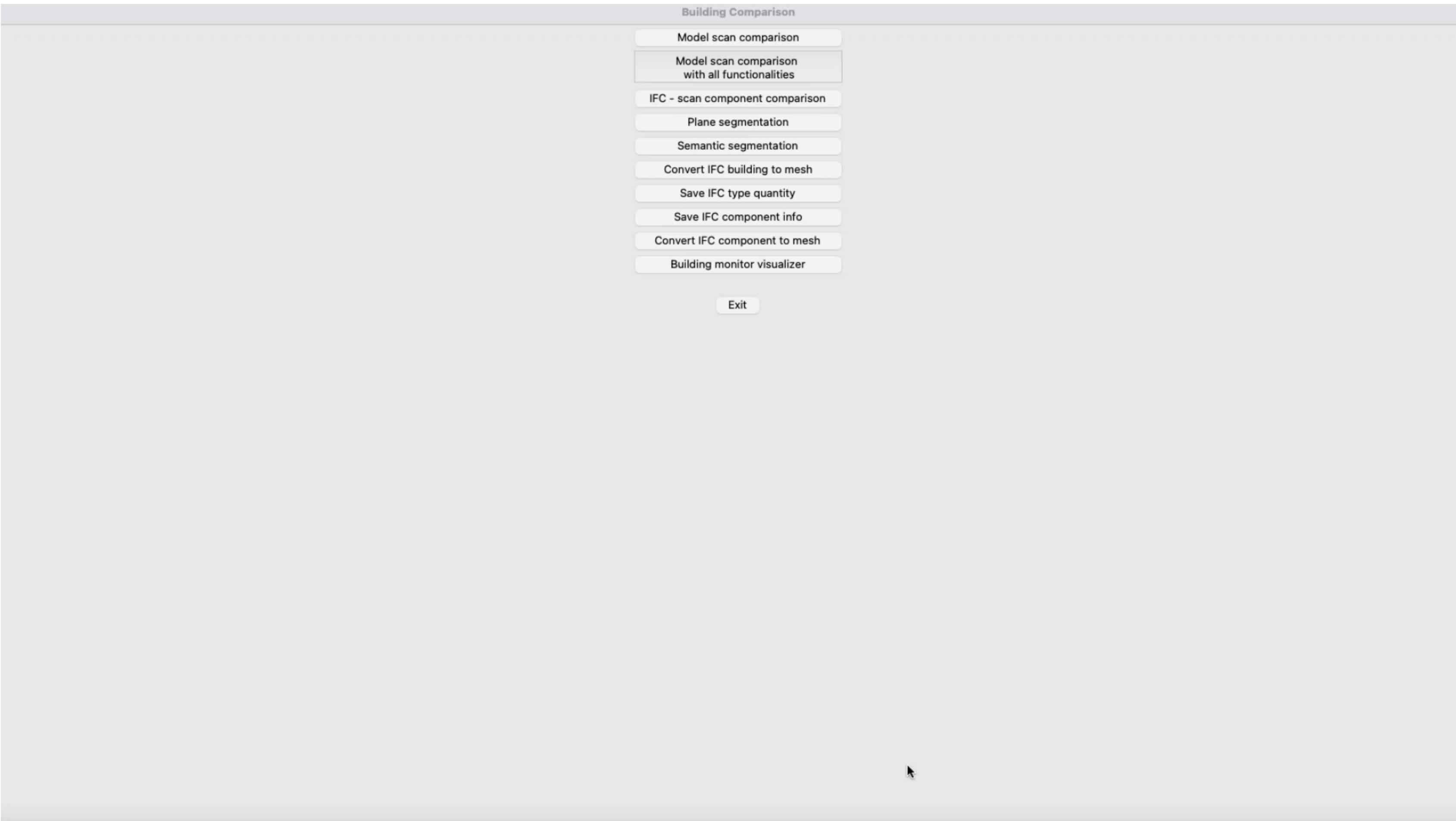


Building Progress Visualizer

Use Case Demo



Use Case Demo

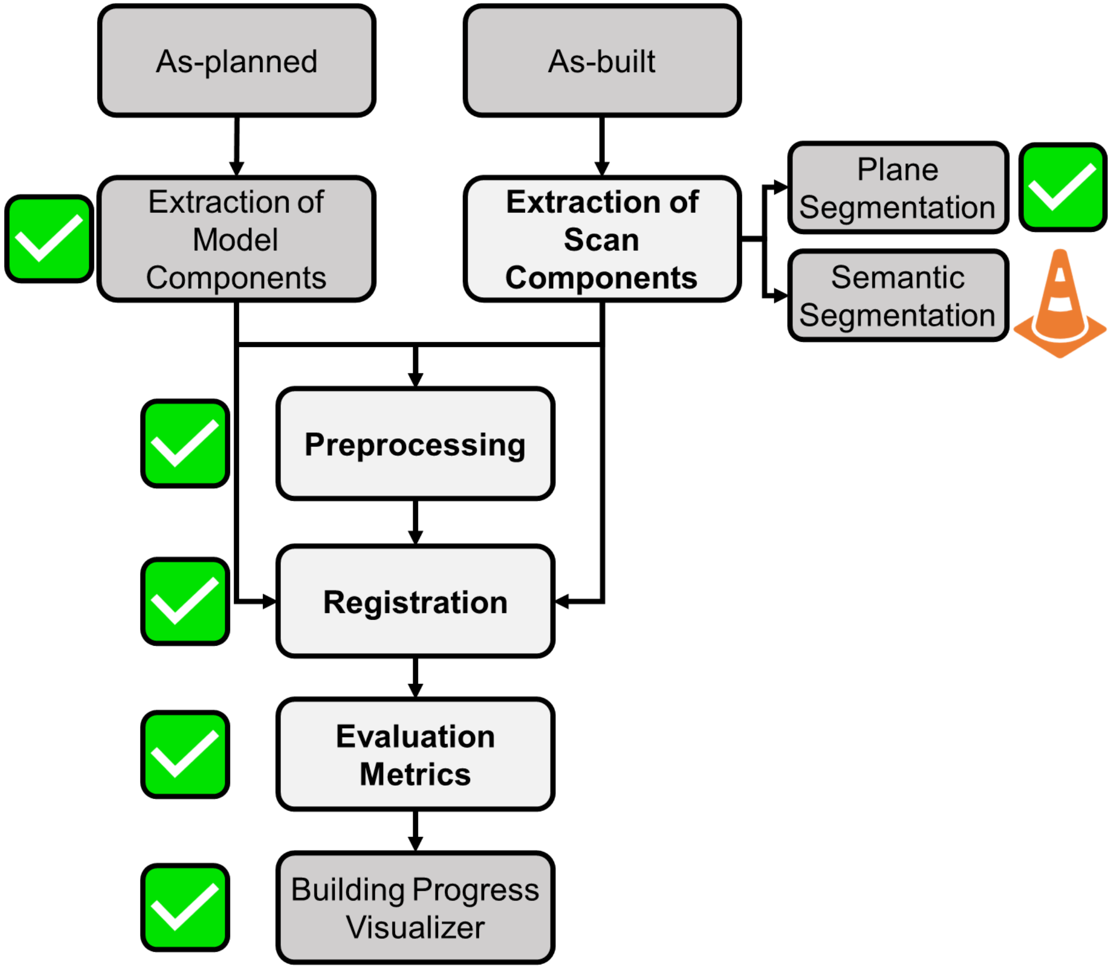


Suggested Future Work

- Compare **schedule** time and **actual** construction time
- **Preprocessing** focusing on **photogrammetry** data

- **Dynamic threshold** parameters with **regression**
- **Improve** mesh to point cloud **conversion**
- Improve semantic segmentation:
  - **Longer training time**
  - **Extend dataset**
- Implement **Unity** application
- **Remove dynamic** objects

Conclusion


As-planned
As-built
Extraction of Model Components
Extraction of Scan Components
Plane Segmentation
Semantic Segmentation
Preprocessing
Registration
Evaluation Metrics
Building Progress Visualizer

List of References

1. Borrmann, A. et al. (2017). “Acquisition and Consecutive Registration of Photogrammetric Point Clouds for Construction Progress Monitoring Using a 4D BIM”. In:PFG – Journal of Photogrammetry, Remote Sensing and Geoinformation Science85, pp. 3–15.
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