

Indoor localisation and location tracking in semi-public buildings based on LiDAR point clouds and images of the ceilings

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Why indoor localisation?

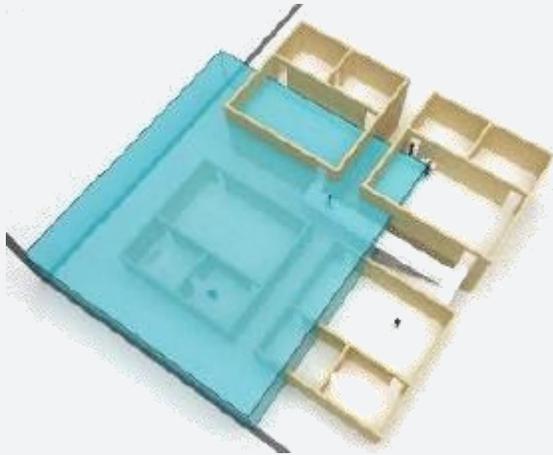
- Bad GNSS reception
- Low landmark density
- Absence of outstanding elements
- Easier loss of orientation

“80-90% of a person’s time is spend indoors”



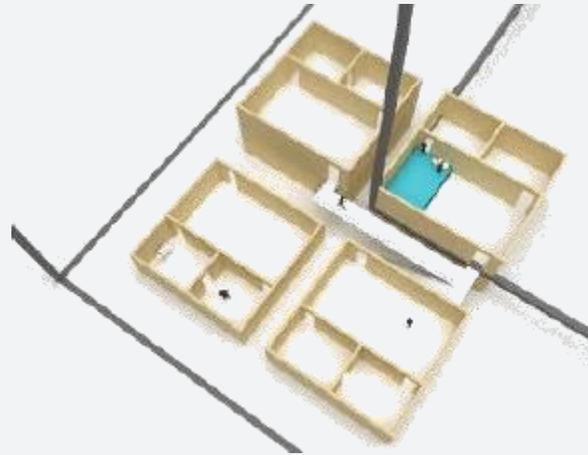
Location vs Position

Absolute Position



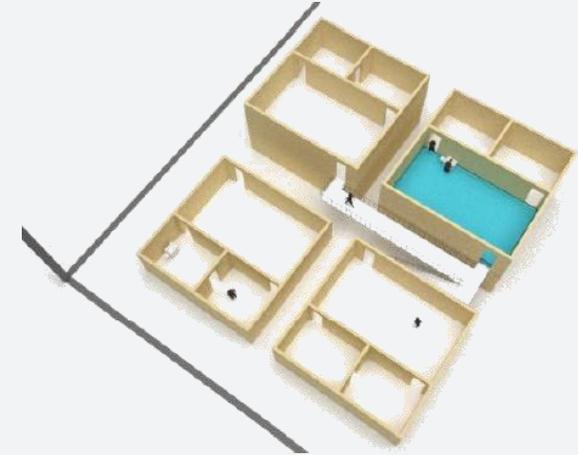
Global Reference System

Relative Position



Local Reference System

Location



Semantic information

Why LiDAR?



Wi-Fi fingerprinting
Augmented Reality
Arduino



Up-to-date radio map
Additional device
Costly

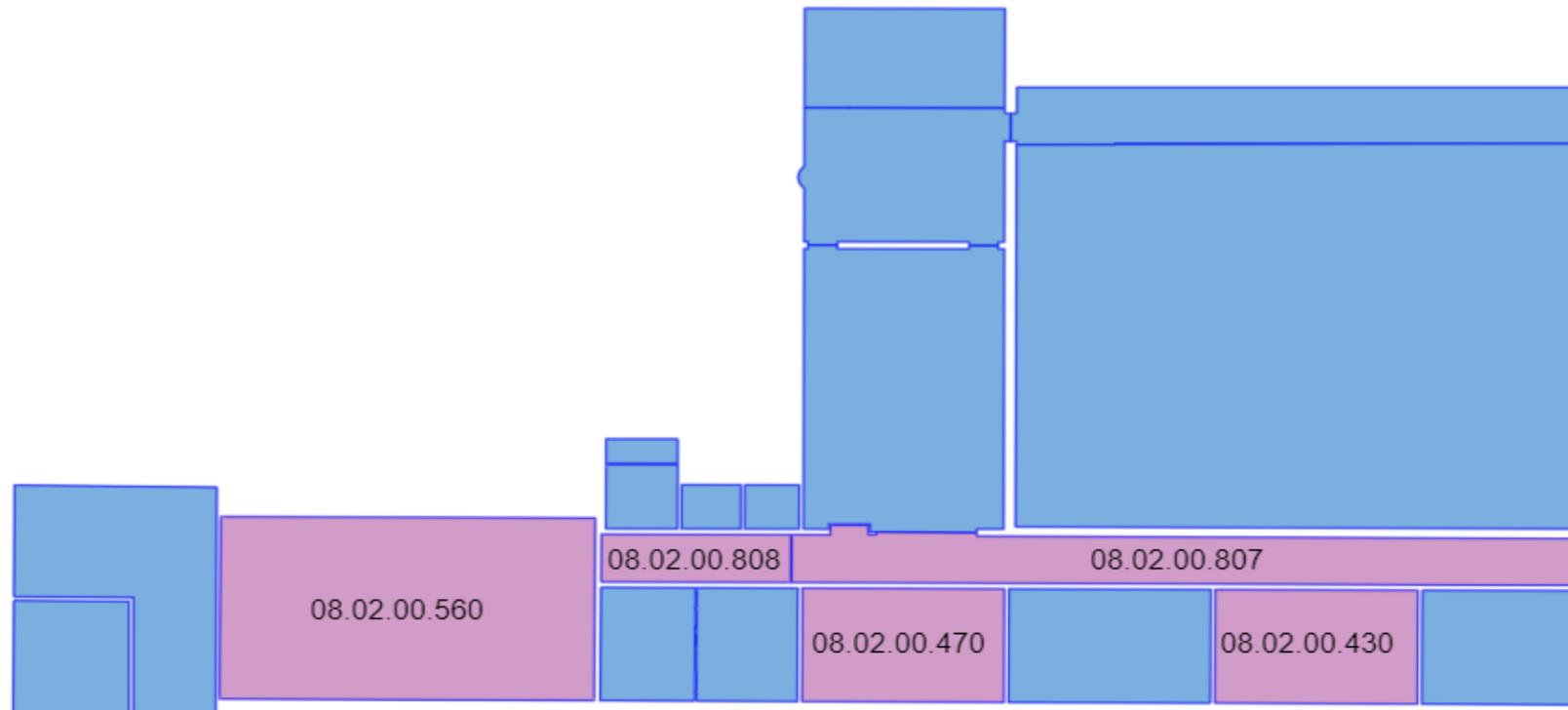
No universal solution!

iPad 12 pro
Scanning apps



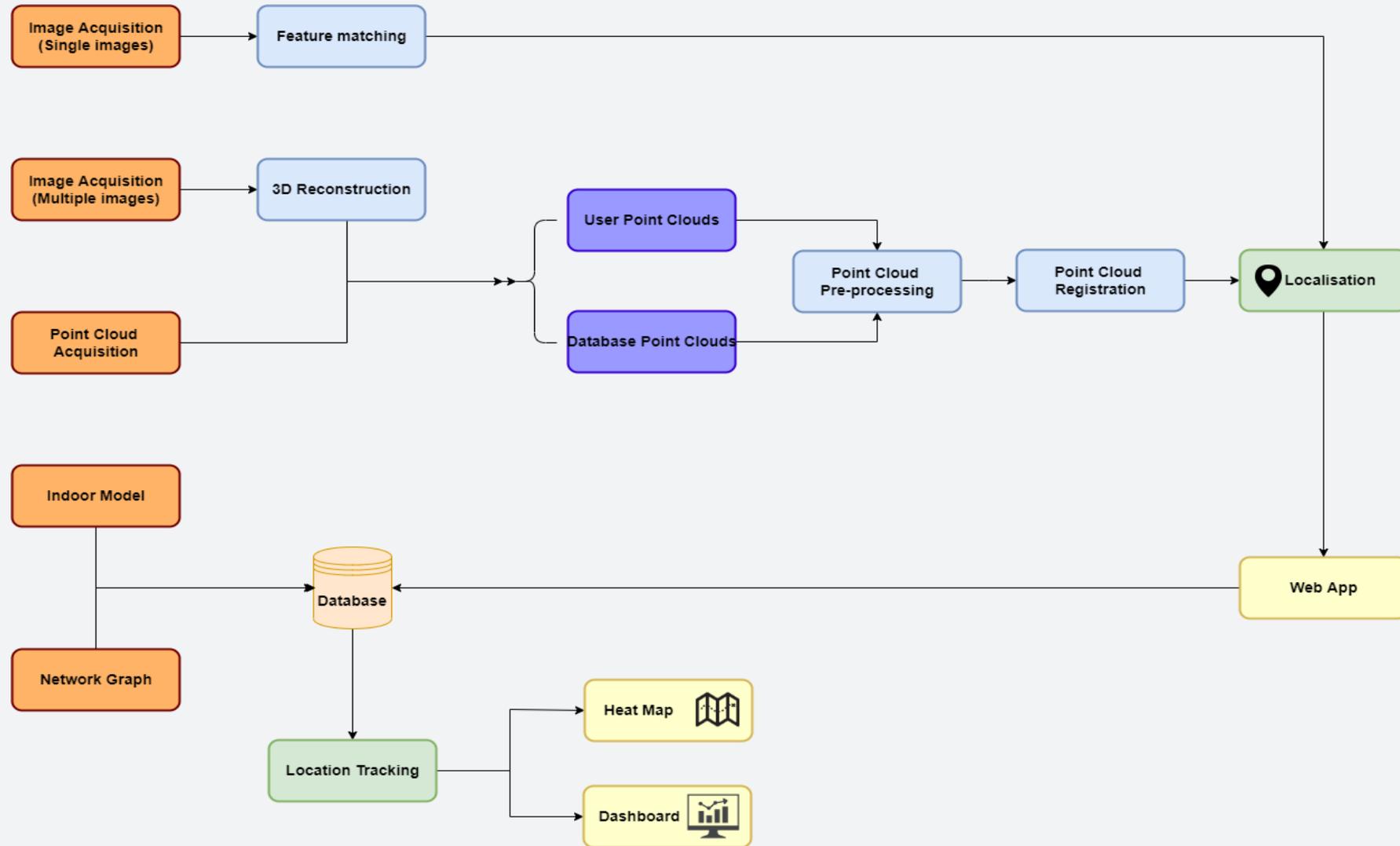
LiDAR & Camera sensors
ARKit

Case study



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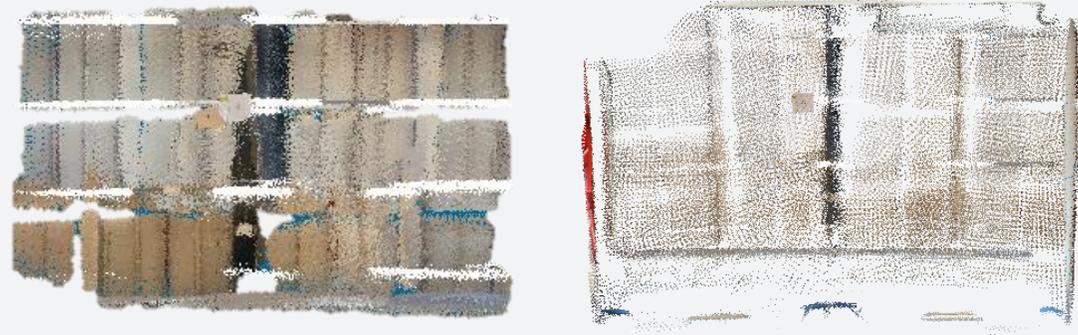
Methodology



Data acquisition

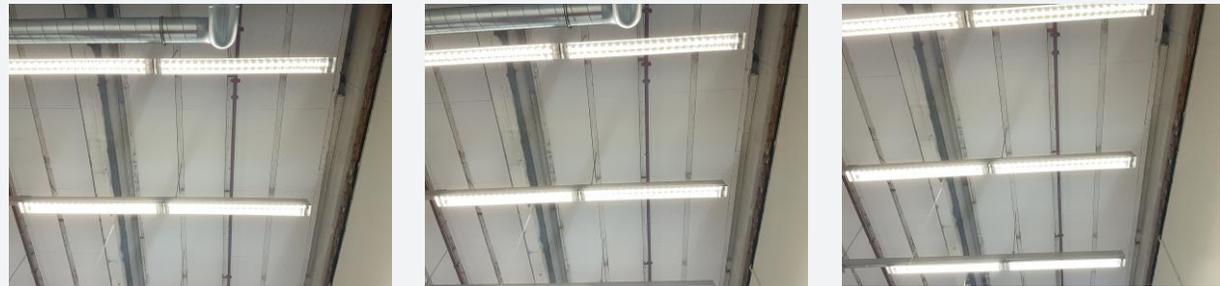
Point Clouds

- SiteScape
 - 10 cm point distance
- Pix4D Catch
 - 30 cm point distance



Images

- Xiaomi Redmi Note 9s
 - 5 MP & 8 MP camera
- Pix4D Catch
 - Overlapping images



Point cloud pre-processing

Original Point Cloud



548031

Downsampling



7359

Outlier removal



6587

Plane Segmentation

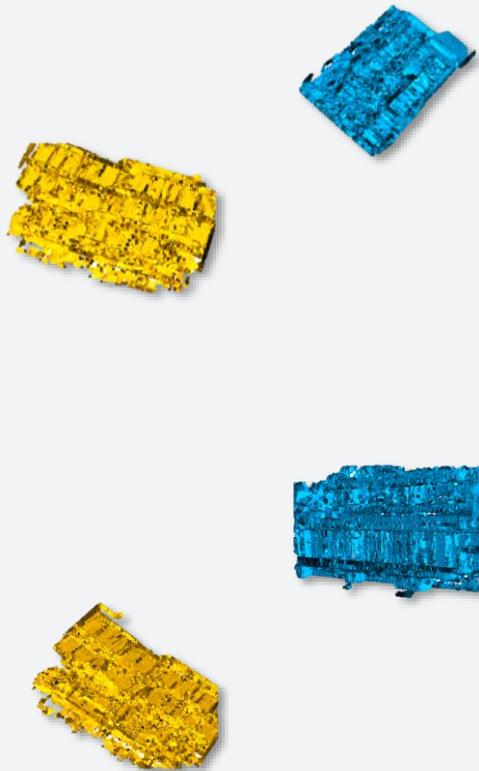


2271

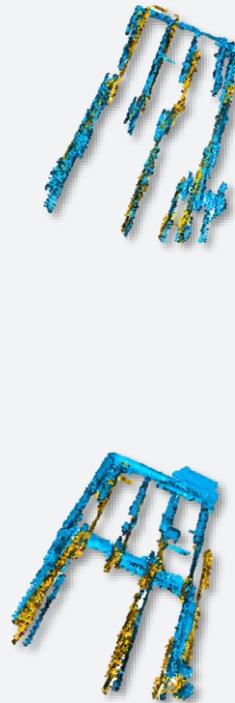
4% of the original point cloud

Point cloud registration

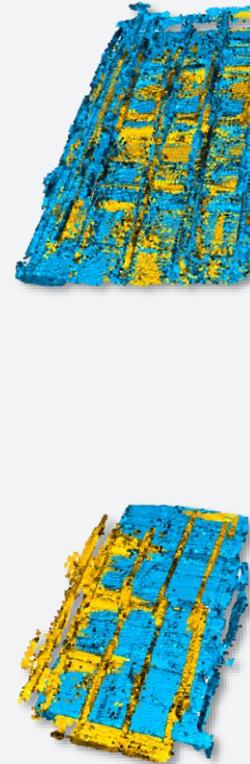
Original Pose



Global Registration



Local refinement



Global & Local registration

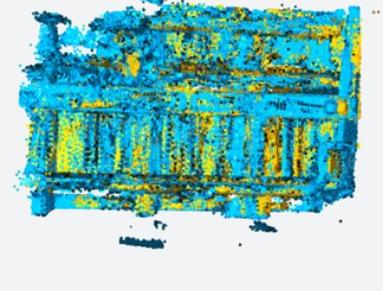
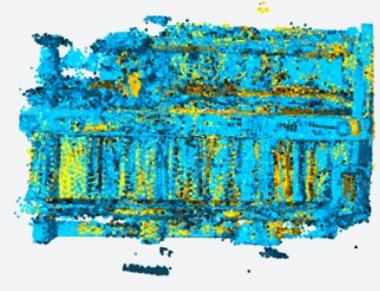
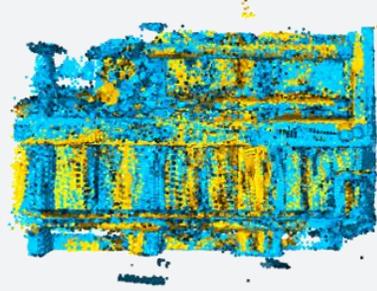
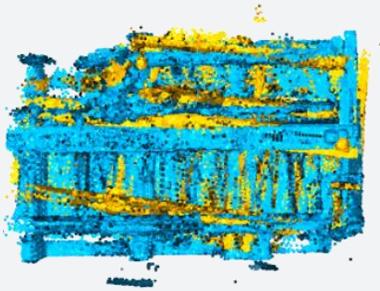
Point-to-Point ICP

Point-to-Plane ICP

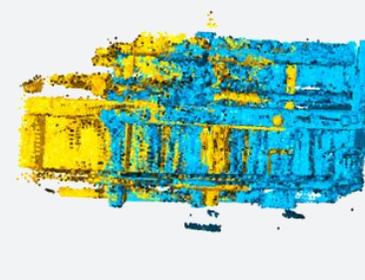
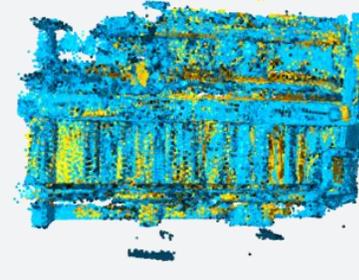
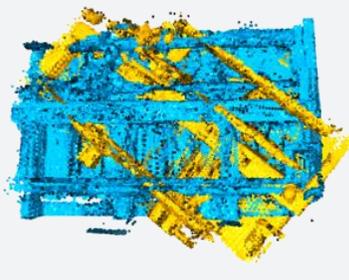
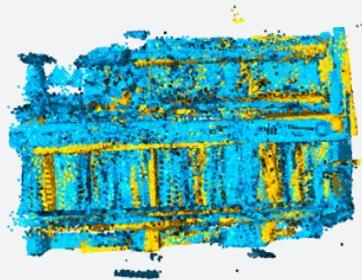
Colored ICP

Generalised ICP

RANSAC

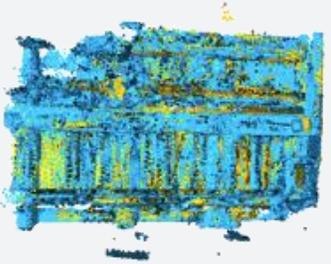


FAST



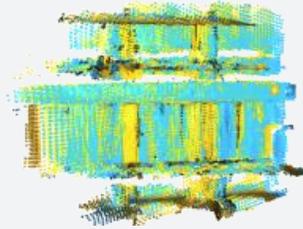
Point-cloud based localisation

SiteScape (10cm)



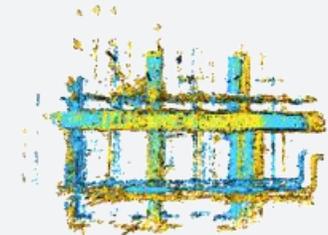
Fitness: 0.974 – RMSE: 0.08

Pix4D Catch (30cm)



Fitness: 0.963 – RMSE: 0.09

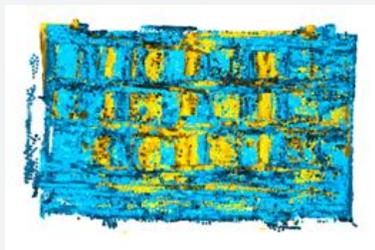
3D reconstruction from overlapping images



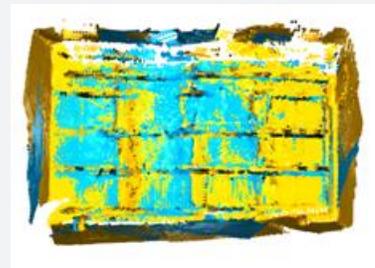
Fitness: 0.778 – RMSE: 0.22

08.02.00.560

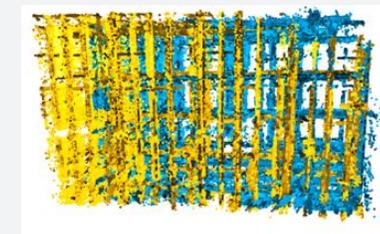
08.02.00.470



Fitness: 0.974 – RMSE: 0.08



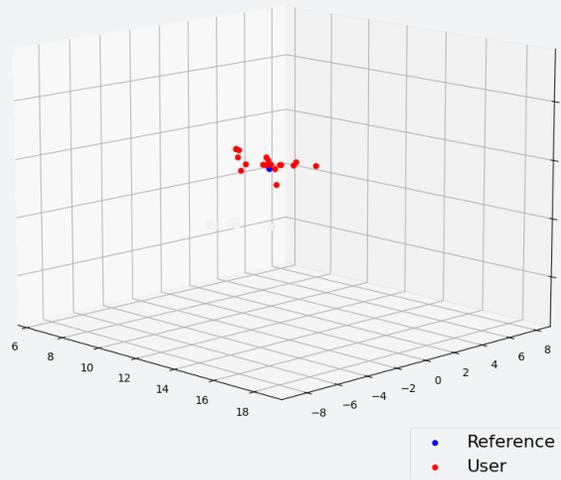
Fitness: 0.726 – RMSE: 0.06



Fitness: 0.571 – RMSE: 0.22

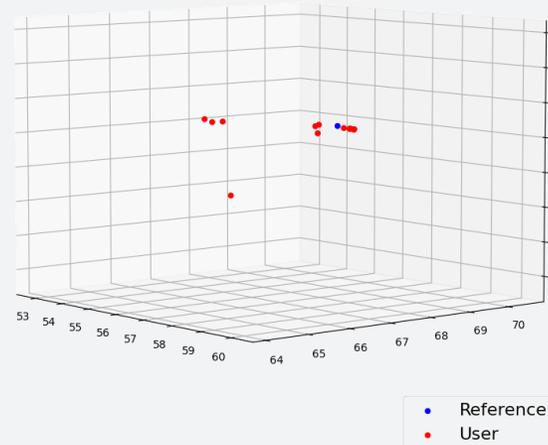
Performance parameters

08.02.00.808



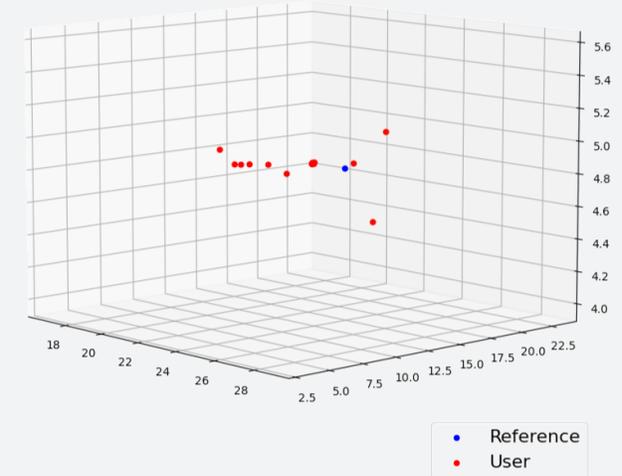
Accuracy ✓
Precision ✓

08.02.00.560



Accuracy ~
Precision ~

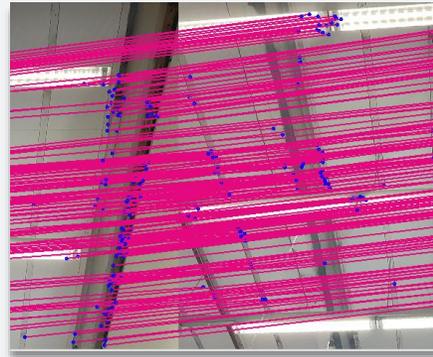
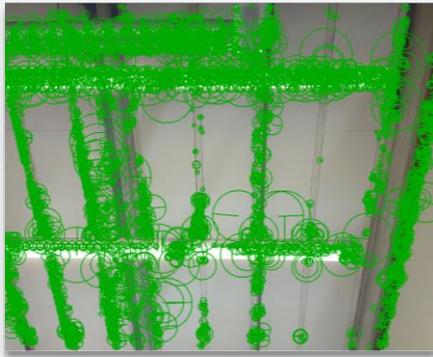
08.02.00.807



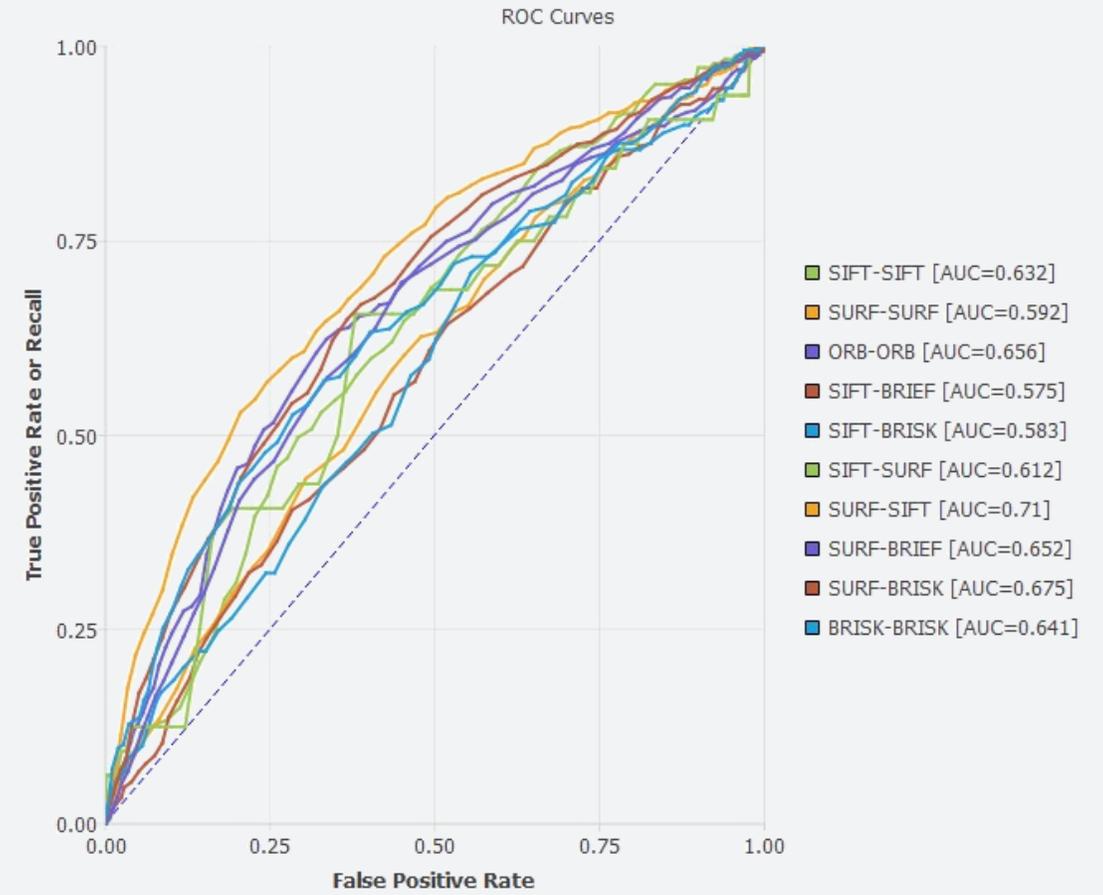
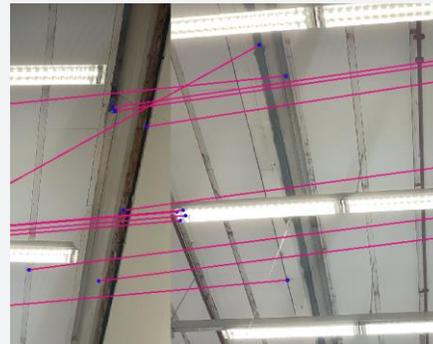
Accuracy ✗
Precision ✗

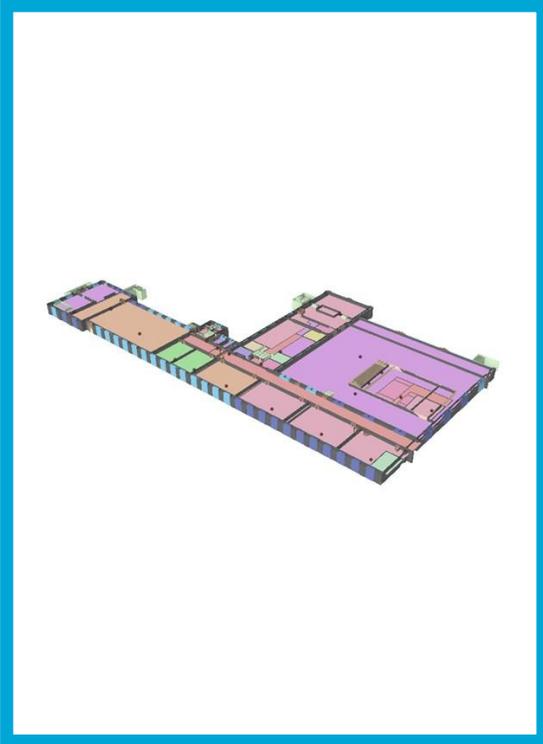
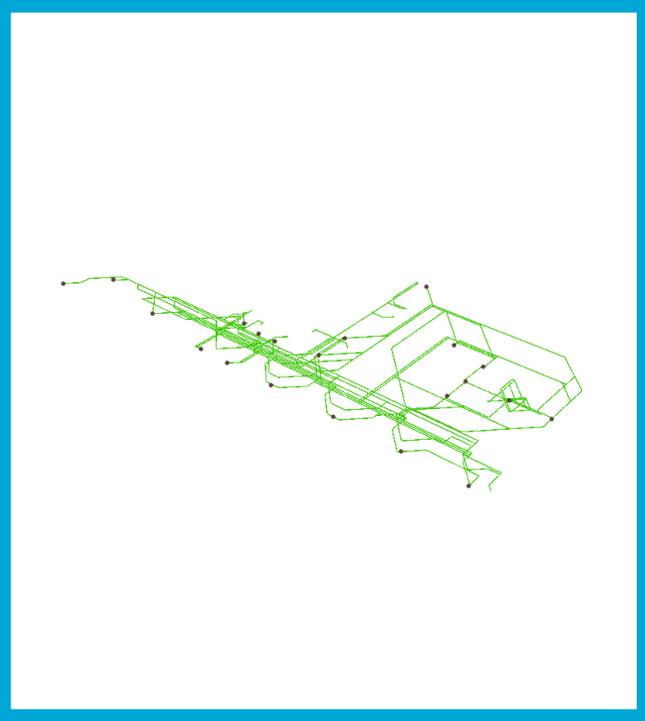
Feature matching

SURF-SIFT



SIFT-SURF





Storage

ArcGIS Online Server

- Indoor model of BK
- Reference point clouds
- Network graph

Web-app

Capabilities

- User location
- Indoor model (background map)
- Zoom & Highlight

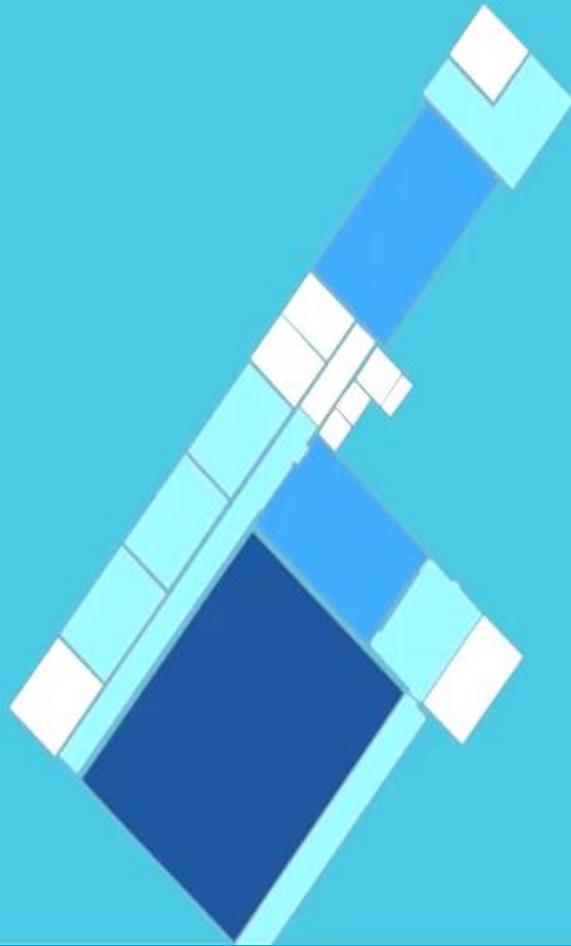


Upload your point cloud

Faculty of Architecture and the Built Environment

Choose File No file chosen

Submit



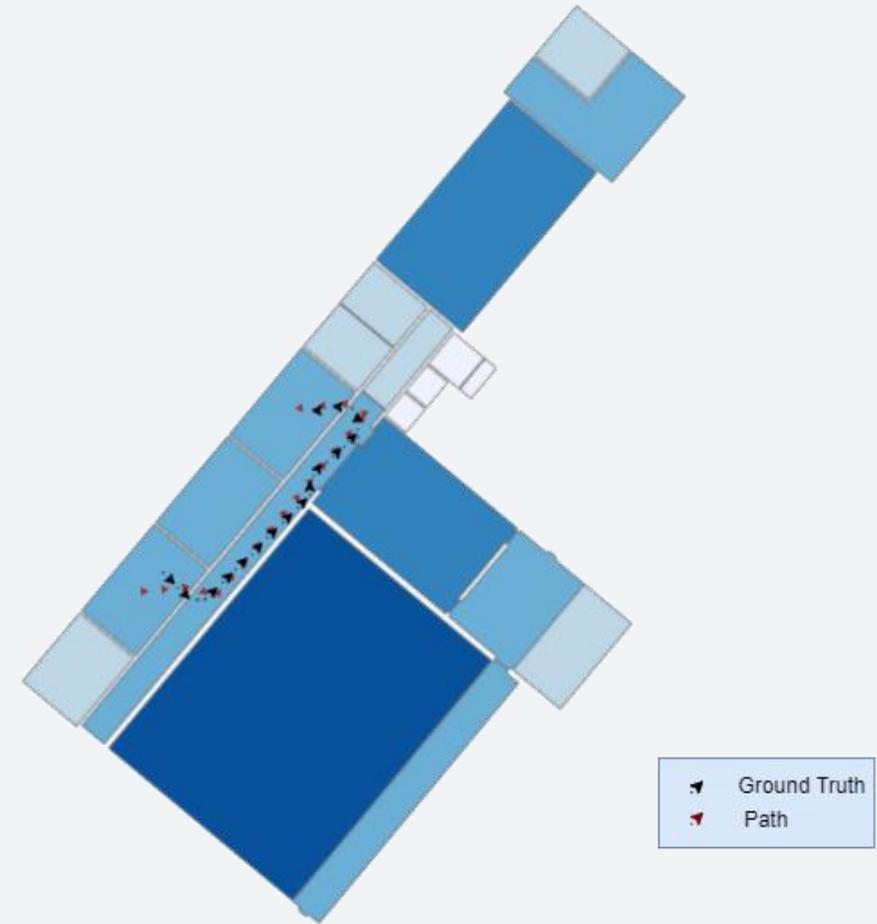
Location tracking

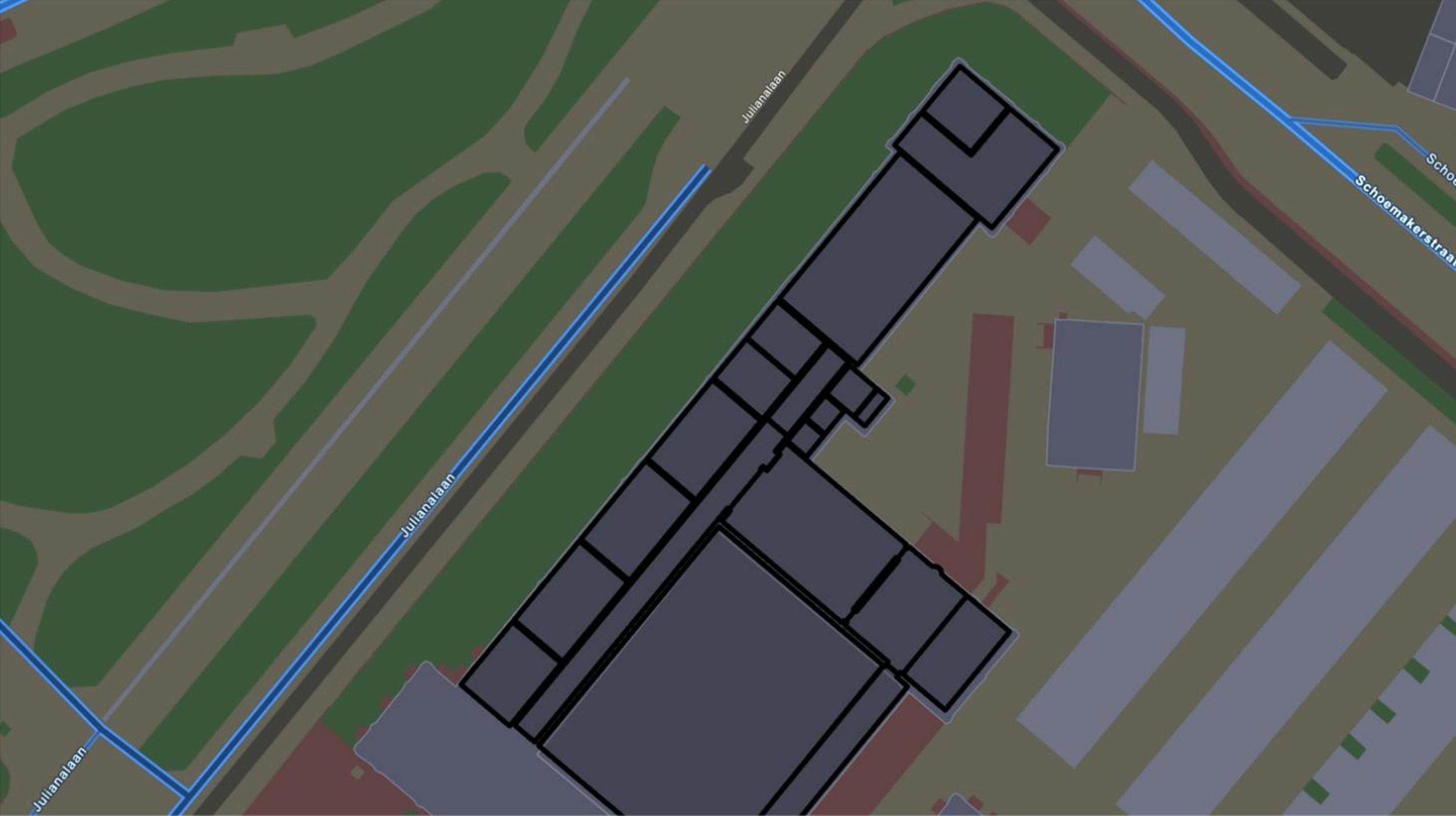
Heat map

- Network graph
- Different color/user
- Room level accuracy

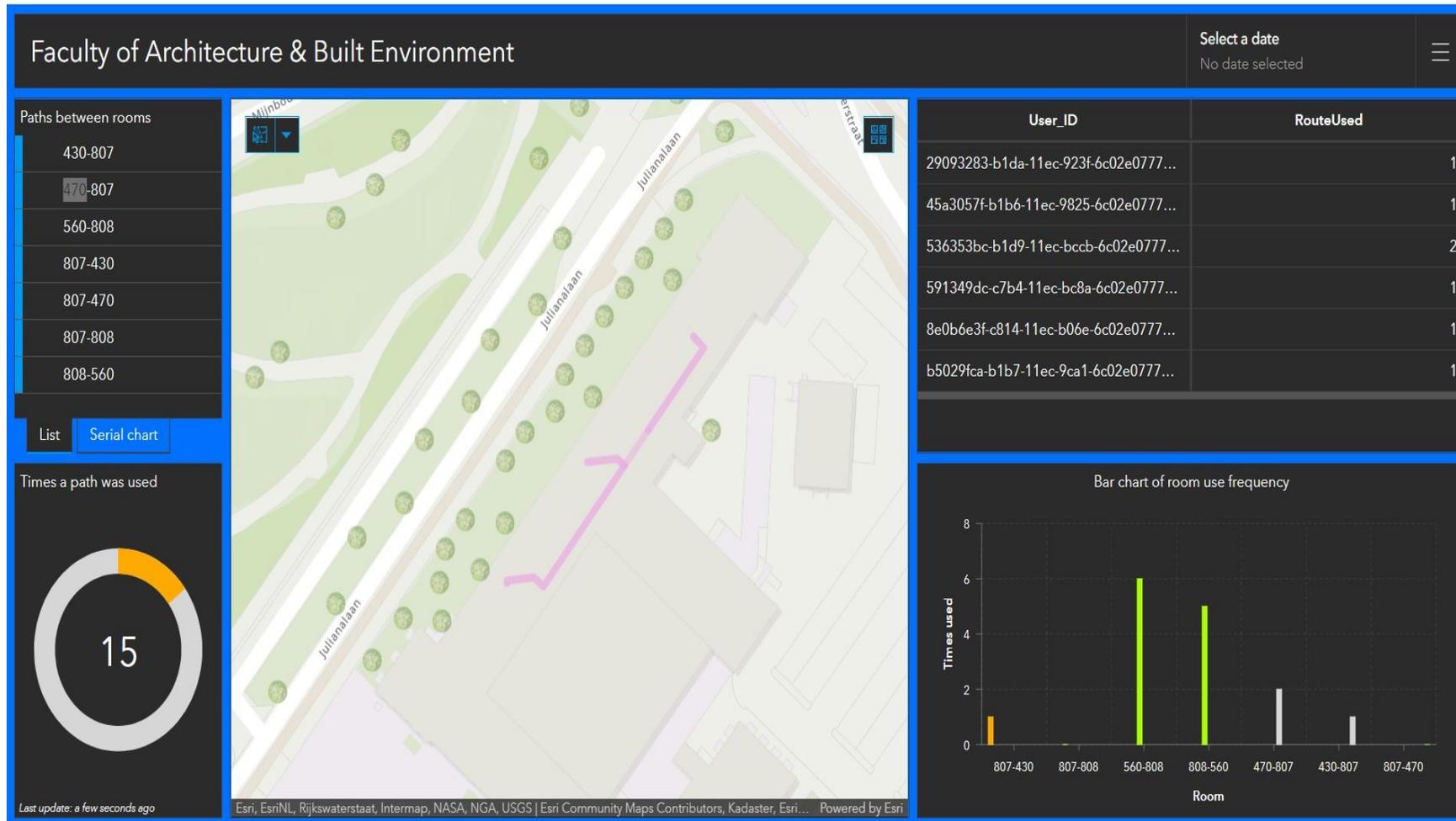
Dashboard

- Daily/weekly/monthly statistics
- Movement patterns
- Optimal distribution of people





Dashboard



Conclusions

“To what extent can ceilings with characteristic details be used for indoor localisation purposes ?”

- *“Which parameters (measuring angle, height, part of the room) should the user take into account while acquiring point clouds and images of ceilings?”*
- *“Which is the optimal point cloud registration algorithm to achieve indoor localisation from ceiling data?”*
- *“Which is the optimal image matching algorithm to achieve indoor localisation from ceiling data?”*
- *“Are LiDAR point clouds acquired by an iPhone device an accurate and accessible solution towards indoor localisation?”*
- *“Can the proposed pipeline aid towards facilitating localisation in emergency situations?”*
- *“How accurate is location tracking and does it respect user privacy?”*

Conclusions

1. Parameters

- Steady pace – no sudden changes
- Hold device perpendicular
- Distinct parts & no walls

2. Point cloud registration

- RANSAC based
- Colored ICP
 - Geometry & Color
 - Time efficiency

3. Image matching

- SURF detector
- SIFT descriptor
- Brute force more efficient but...

4. Emergencies

- Dataset size
- Improvements required
- Type of emergency

5. LiDAR Sensor

- Accessible ✓
- Accurate ✓

6. Location tracking

- Localisation dependent
- Room level
- Random ID / user

Conclusions

“To what extent can ceilings with characteristic details be used for indoor localisation purposes ?”

Strengths

- + Room level localisation
- + Real time localisation
- + Static & dynamic acquisition
- + Ceilings with characteristic details

Areas of improvement

- 3D reconstruction
- Range of LiDAR sensor
- Flat & Glass ceilings



Applications

Basis for navigation

Affirmation that a user is on the correct route

Emergency situations

Mapping of an indoor facility

Optimal distribution of people

Reference to BIM and CAD drawings

Limitations



Data acquisition

Non – Universal solution

Range of LiDAR

PLY files



Pre-processing:

Non-automated
parameters

Partial wall clean up



Indoor localisation:

First localisation
efficiency

Single image cannot
entirely cover large
rooms



Web – app:

Beta web-app version



Location tracking:

Dashboard adjustment

Recommendations

Testing with different ceiling types

Testing in Android devices

Testing in large scale environments

Testing in sub-room level

Combination with Wi-Fi fingerprinting

Testing of images under different illumination conditions

Orthomosaic from a collection of images

Future work

Machine learning

- Automatic wall detection
- Monocular depth estimation

Landmark – based indoor localisation

- AR device for utility inventories

Indoor navigation:

- Navigation instructions
- Navigation between less occupied spaces
- Integration with other sensors (humidity, temperature)

User groups:

- People with partial/severe blindness
- Paraplegic/quadriplegic users

An aerial photograph of a large, historic university building complex. The main building is a multi-story structure with a dark roof and a prominent central tower. It is surrounded by lush green trees and other smaller buildings. The scene is captured from a high angle, showing the layout of the campus and the surrounding urban environment.

Thank you for your attention !!!