# Water Pipe Trench Profile Analysis with 3D point cloud

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# Introduction

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Water pipe installations are one of the most essential parts of the Waterworks authority.

Proper installation practice and confirming to the standard guidelines will ensure lower maintenance and long lasting water pipes.

Mistakes when digging the trench such as incorrect trench width/depth or inconsistent trench profiles will lead to damages in the water pipe.

# Introduction

- I measured the real trench profiles with measure tape to use as ground truth.
- I collected the data with mobile phone camera and depth sensor.
- I measured the trench profiles with 3D point cloud to check whether if the trench are within the specification followed.

# Advantage of analyzing with 3D point cloud

- 3D point cloud can be used to visualize the trench.
- Normal user can measure the trench with MeshLab.
- Trench can be analyzed by specific section.
- Algorithm can also be developed to measure the trench automatically.

# Sensors Used

- Mobile phone camera
- Intel Realsense D455 (RGB-D sensor)

Intel Realsense D455

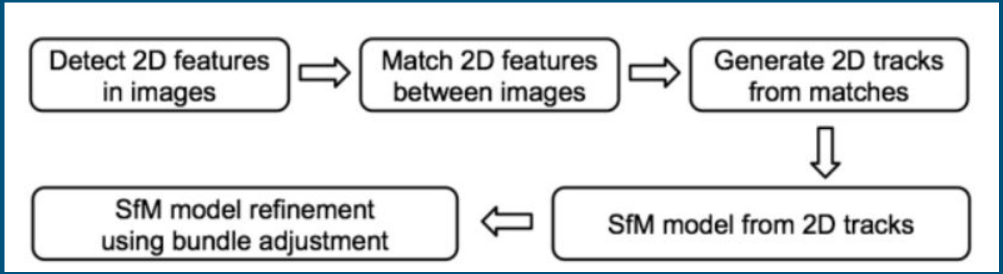
# RGB-D Sensors

- Depth-sensing devices that work in association with a RGB sensor camera
- Provide depth information in a per-pixel basis.
- Provide 3D point cloud with real dimensions

# 3D Point Cloud Collection Process

# Collected from Mobile Phone Camera + SFM

- Captured video
- Calibrated Camera
- Selected keyframes from the collected video by phone
- Undistorted the key frames
- Loaded them in Key frames of OpenSFM and RUN OpenSFM
- *In config: depthmap_min_consistent_views: 6*



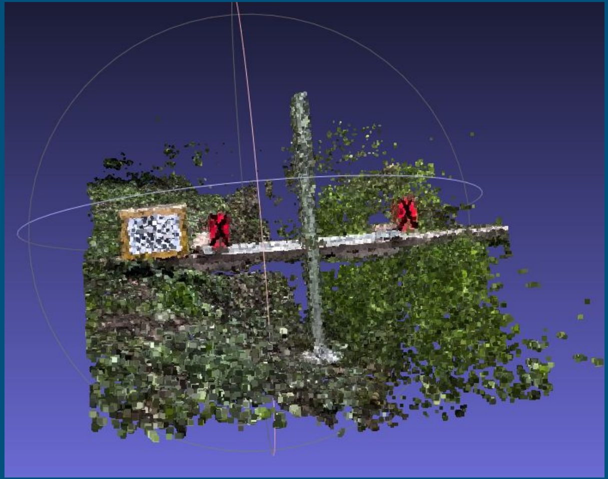

Steps of Structure from Motion (SFM) Process

# Sample frames from collected videos

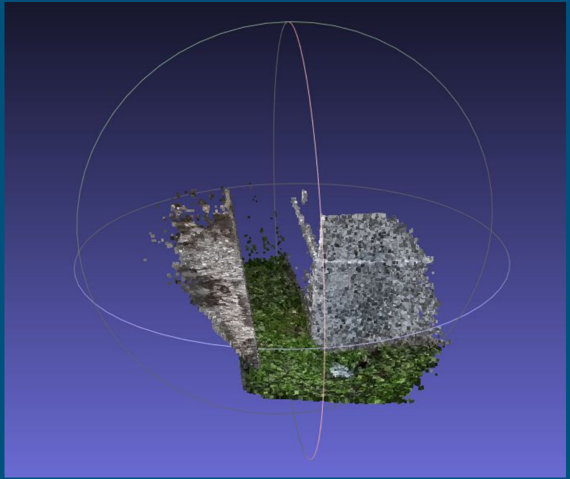
Trench 1: near student village 3

Trench 2: near V Dorm

# Reconstructed 3D point cloud from SFM



Trench 1

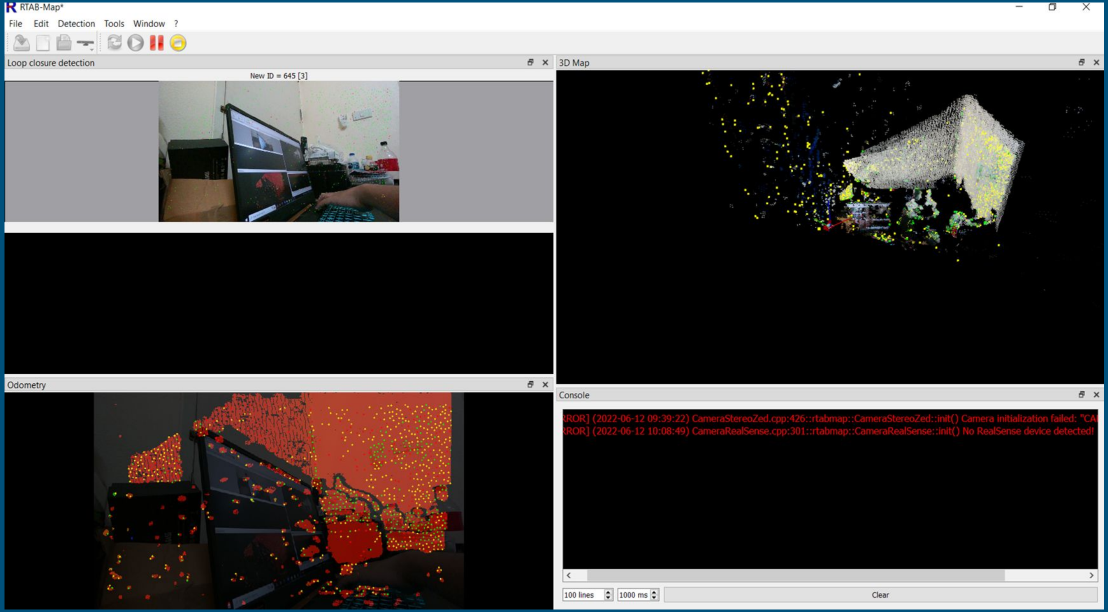


Trench 2

# Collected from Intel Realsense D455

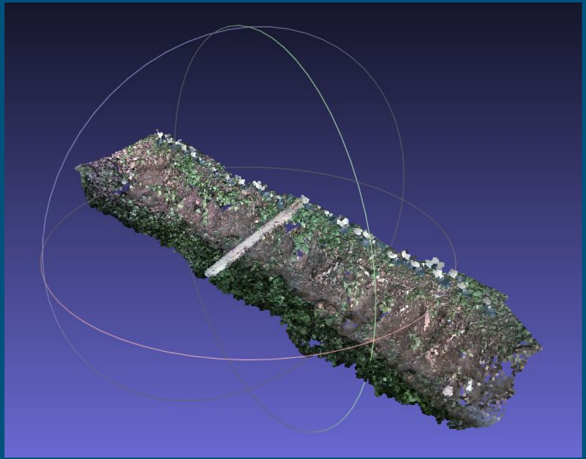
- Record Data in RTAB-Map
- Record 3D point cloud
- Save 3D point cloud in “ply” format.

RTAB-Map Logo

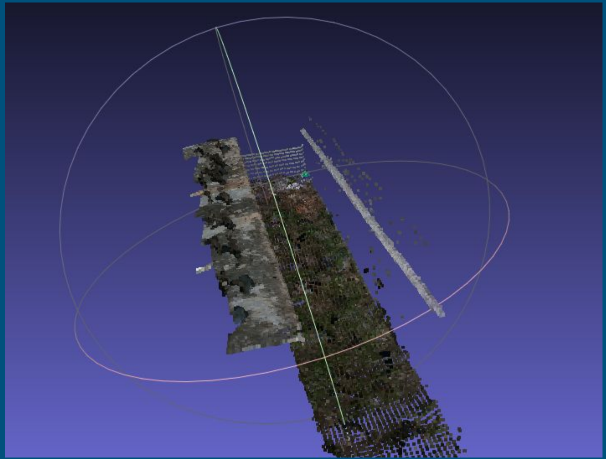



Sample Process about How to Record 3D point cloud in RTAB-Map

# 3D point cloud collected from Intel Realsense D455



Trench 1



Trench 2

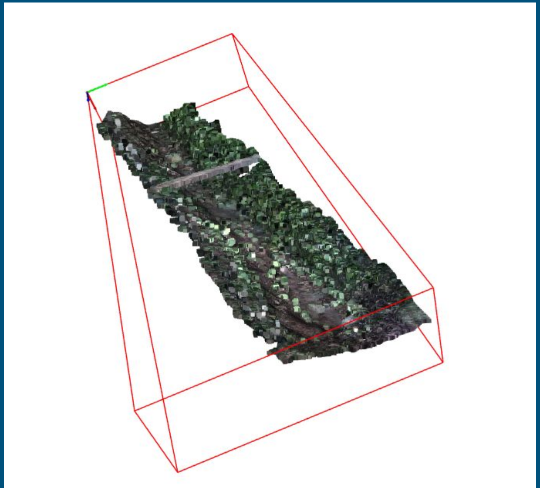
# Trench Profile Measuring Process

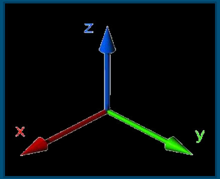
# Cropping 3D point cloud

- Observed 3D Point Cloud.
- *Point Cloud Library: Open3D*
- Removed Outliers with Statistical outlier removal
- Created a bounding box for whole 3D point cloud
- Rotated 3D point cloud to be fit properly in bounding box.
- Manually selected the section of 3D Point Cloud and cropped it for measurement.
- Saved it in “ply” format.

# Rotating 3D Point Cloud

```
Rotation Matrix:
 [[ 0.98106026 -0.17298739  0.08715574]
 [ 0.18591458  0.96721824 -0.17298739]
 [-0.05437399  0.18591458  0.98106026]]
```





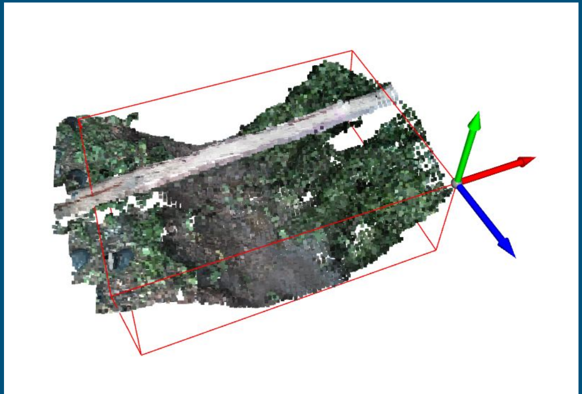

+10 Degree at x axis
+5 Degree at y axis
+10 Degree at z axis

# Bounding Box Measurement

- Cropped 3D point cloud again for detail measurement.
- Drew Bounding Box on cropped 3D point cloud.
- Using maximum and minimum bounding points in x, y ,z , calculated the trench profiles
  - Width = (X_max - X_min ) * 100  cm
  - Height = (Y_max - Y_min ) * 100  cm
  - Length = (Z_max - Z_min ) * 100  cm

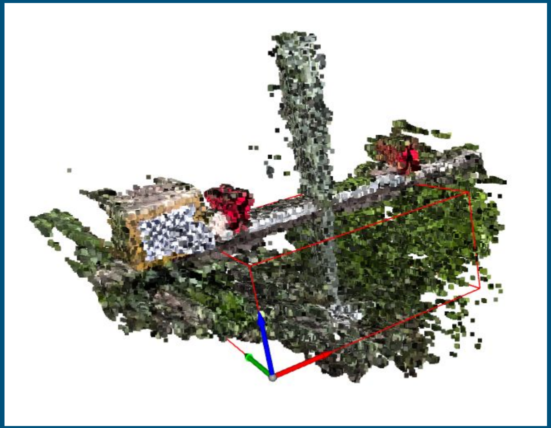
# Record of Bounding Box Measurement

Trench 1 from Intel Realsense



```
Width of trench 214.7230692712406 cm
Height of trench 73.6397178706654 cm
Length of trench 152.1357151238031 cm
```

Trench 1 from Mobile Phone



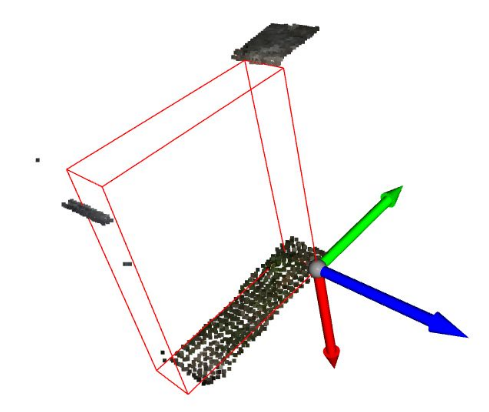
```
Width of trench 227.77000000000004 cm
Height of trench 97.08 cm
Length of trench 177.82 cm
```

# Scale Down Trench 2 from Mobile Phone

- It is 10 time Bigger than what it should be.
- I scaled it down to 0.1 scale.

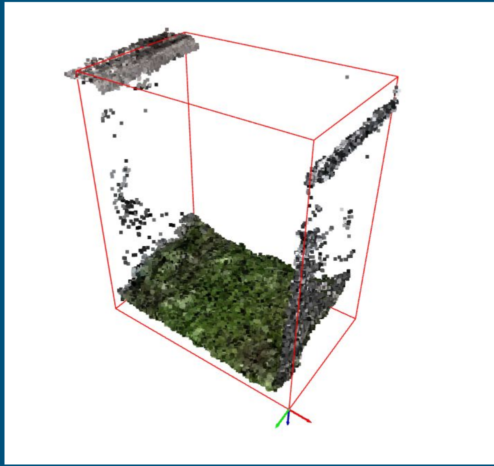
# Record of Bounding Box Measurement

Trench 2 from Intel Realsense



```
Width of trench 67.22118854522705 cm
Height of trench 81.57196044921875 cm
Length of trench 16.1288321018219 cm
```

Trench 2 from Mobile Phone



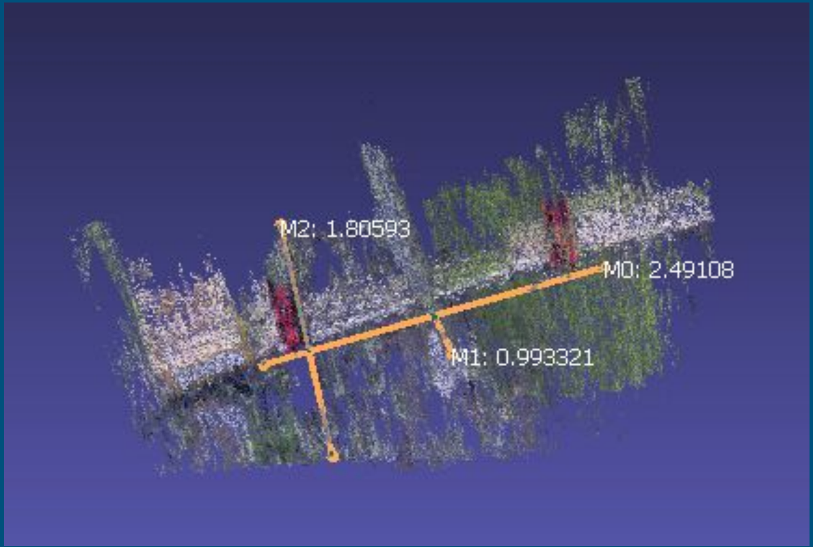
```
Width of trench 55.85900000000001 cm
Height of trench 67.76 cm
Length of trench 35.298 cm
```

# MeshLab Measurement

- Imported the cropped 3D point cloud.
- Selected the two points to measure the distance between these two points.

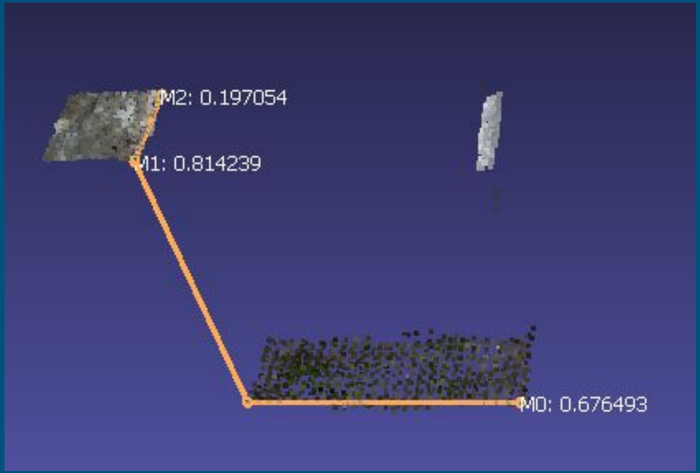
# Record of MeshLab Measurement


Trench 1 from Intel Realsense

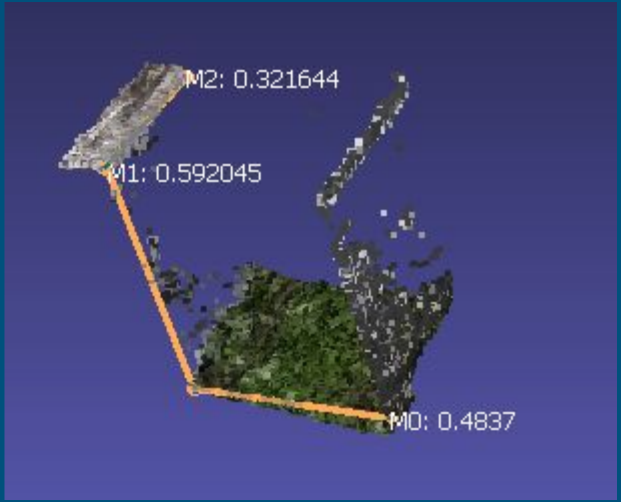



Trench 1 from Mobile Phone

# Record of MeshLab Measurement




Trench 2 from Intel Realsense




Trench 2 from Mobile Phone

# Result

# Measurement Result Table

| Method | Method of Data Collection | Trench 1 | | Trench 2 | |
|---|---|---|---|---|---|
| | | Width (cm) | Depth (cm) | Width (cm) | Depth (cm) |
| Ground Truth | Measure Tape | 213 | 70 | 69.5 | 78.5 |
| Bounding Box | Mobile phone | 227.77 | 97.08 | 65.01 | 50.28 |
| | Intel Realsense D455 | 214.72 | 73.64 | 67.22 | 81.57 |
| MeshLab | Mobile phone | 249.11 | 99.33 | 48.37 | 59.20 |
| | Intel Realsense D455 | 202.85 | 67.59 | 67.65 | 81.42 |

# Percent Error Comparison

| Method | Method of Data Collection | Trench 1 Percent Error (%) | | Trench 2 Percent Error (%) | |
|---|---|---|---|---|---|
| | | Width | Depth | Width | Depth |
| Bounding Box | Mobile phone Camera | 6.93 | 38.68 | 6.46 | 35.99 |
| | Intel Realsense D455 | **0.81** | 5.2 | 3.28 | 3.91 |
| MeshLab | Mobile phone Camera | 16.95 | 41.9 | 30.40 | 24.59 |
| | Intel Realsense D455 | 4.77 | **3.44** | **2.66** | **3.72** |

# Limitation

- Human error in rotating and cropping 3D point cloud.
- Human error in selecting points of 3D point cloud in MeshLab.

# Future Work

- Implement an algorithm to place any 3D point cloud dataset fit to x, y ,z for width, height a
- nd length of the 3D point cloud
- Implement an algorithm to automatically rotate 3D point cloud to get close to the axis
- Implement an algorithm to automatically crop 3D point cloud to get more accurate bounding box measurement

# Conclusion

- Collected the 3D point cloud
    - with mobile phone camera + SFM
    - with Depth sensor
- Analyzed the trench profile with 3D point cloud in 2 different measurement approaches.
    - Bounding Box
    - Mesh Lab
- Obtained closer measurement value to ground truth value in both measurement approaches with 3D point cloud from depth sensor
- Results could be better
    - with clean trench
    - with stable position of the depth sensor while measuring

# Thank You

# Statistical outlier removal

**statistical_outlier_removal** removes points that are further away from their neighbors compared to the average for the point cloud. It takes two input parameters:

- Nb_neighbors: specifies how many neighbors are taken into account in order to calculate the average distance for a given point.

- Std_ratio:  allows setting the threshold level based on the standard deviation of the average distances across the point cloud. The lower this number the more aggressive the filter will be.