A Comparative Analysis of Refraction-Aware SfM, Hierarchical Localization, and Gaussian Splatting for Underwater 3D Reconstruction

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3D Underwater 2025 – TU Wien

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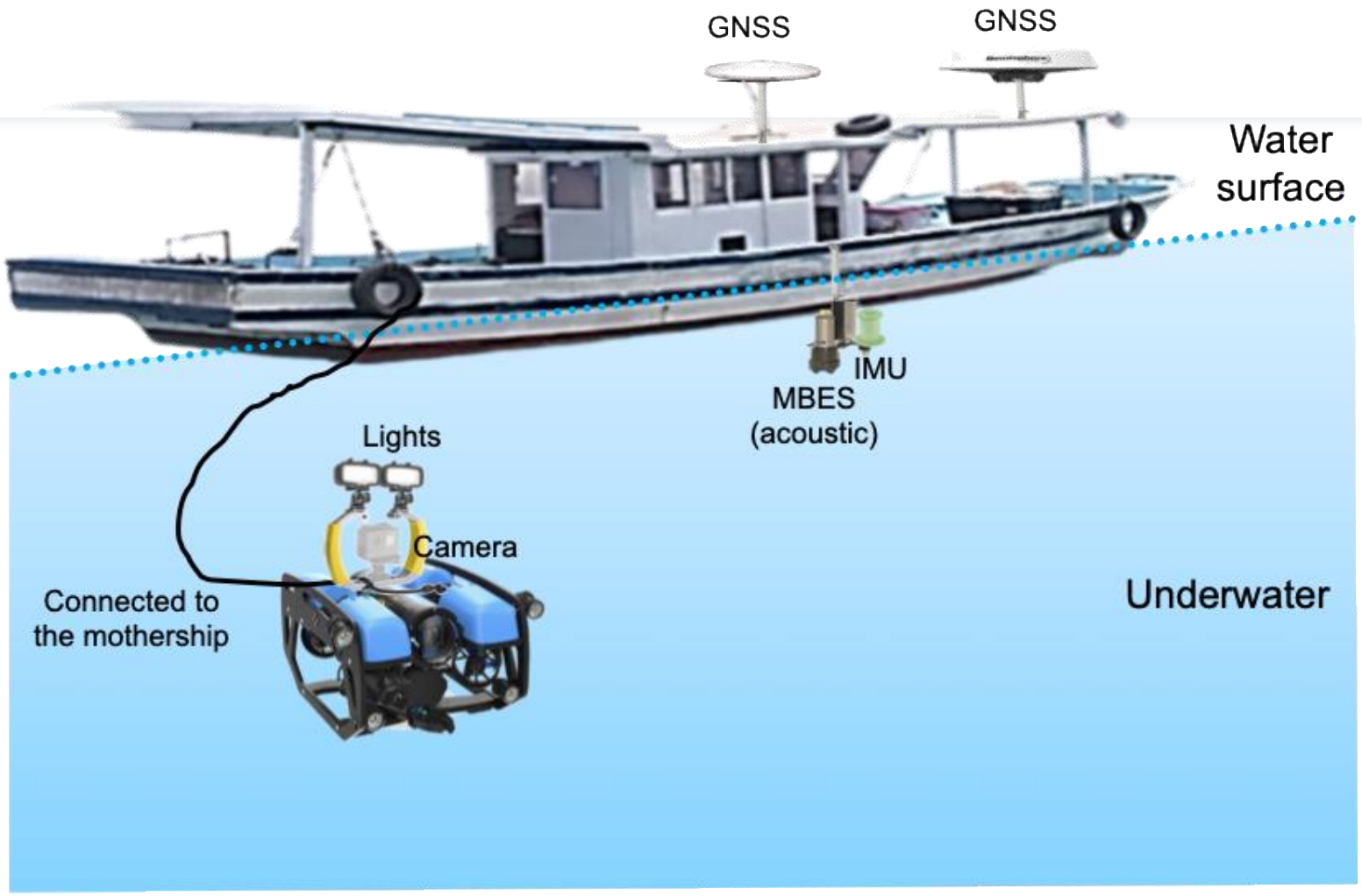
Introduction

Trends in hydrography



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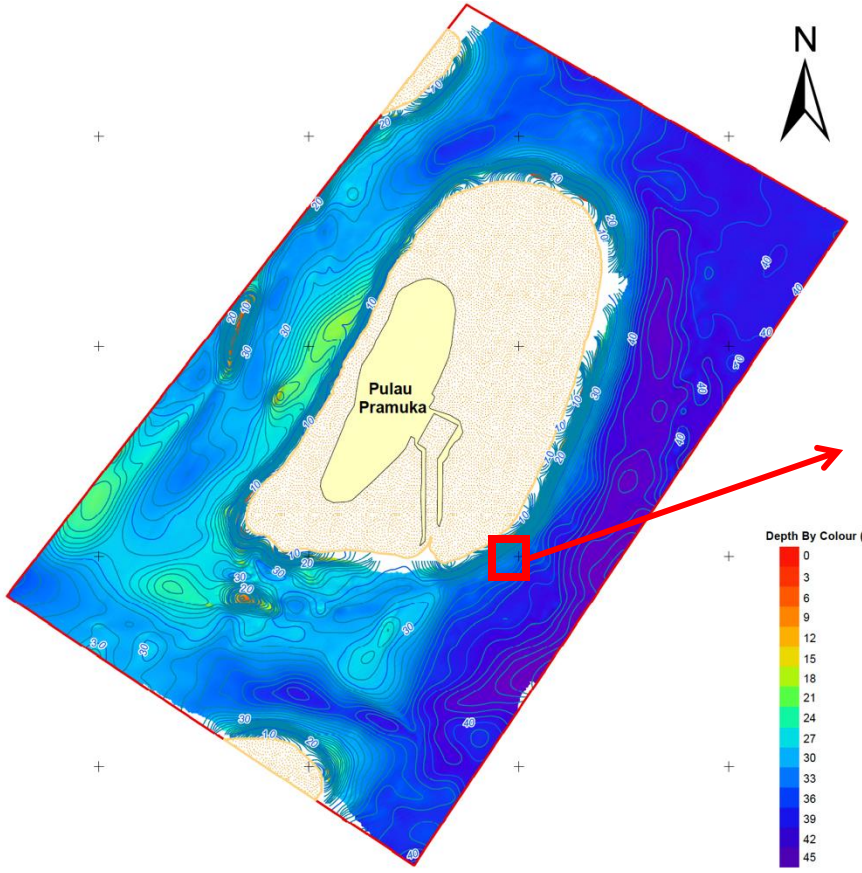
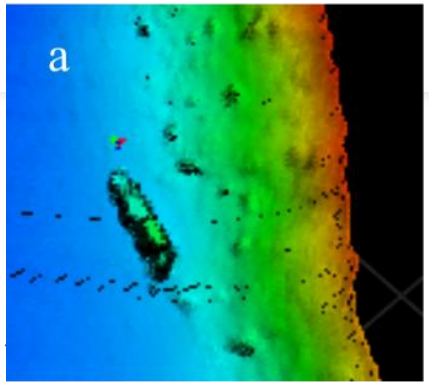
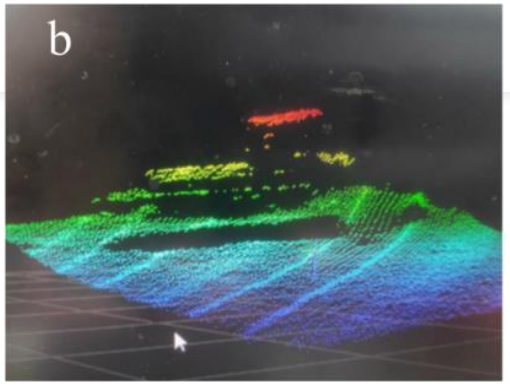
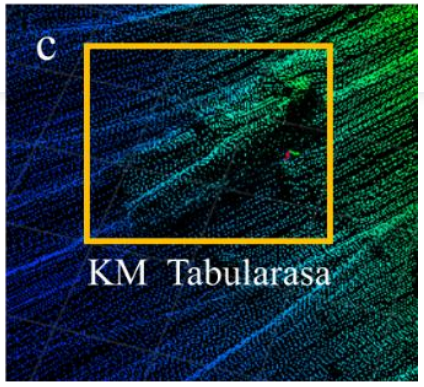
Introduction

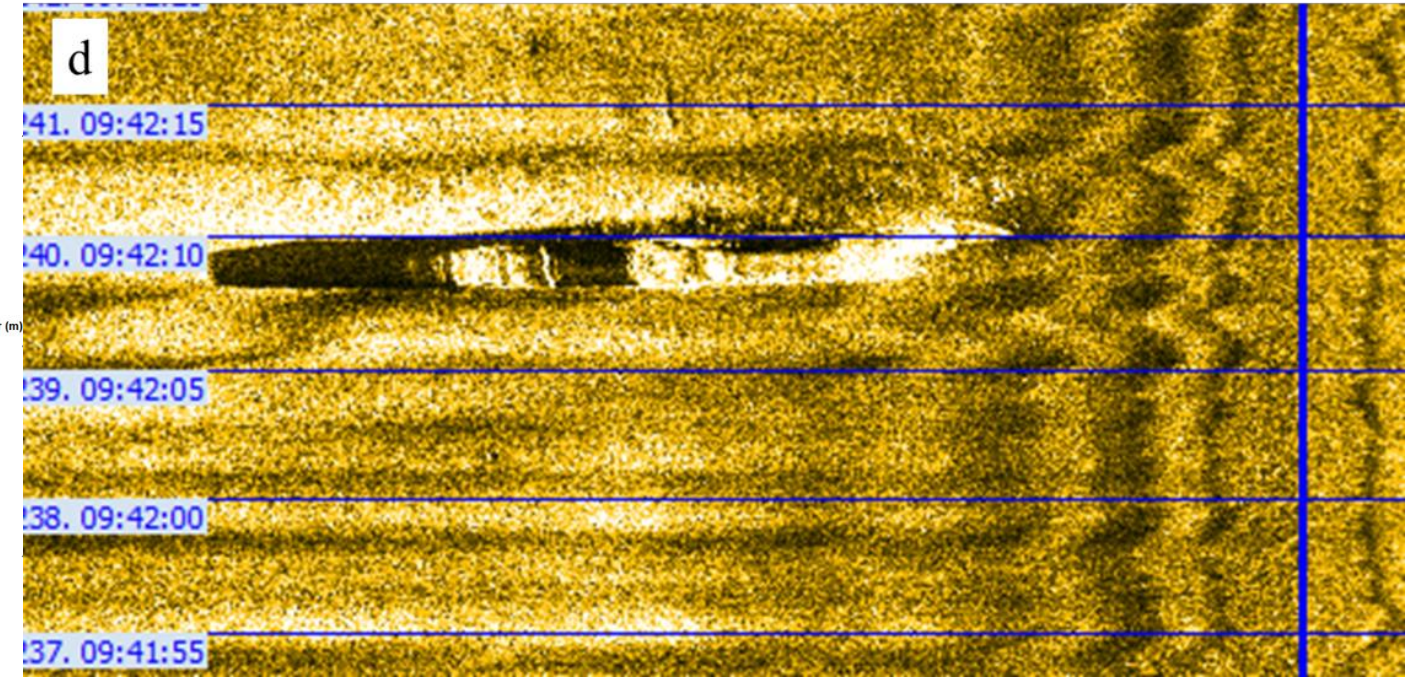
Standard IHO survey





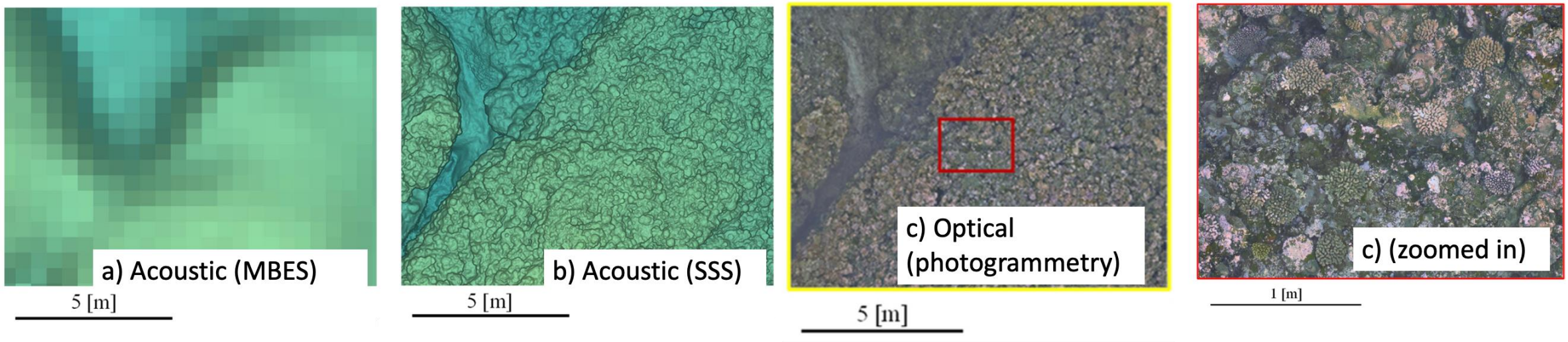






Introduction

Underwater Photogrammetry



Mizuno et al (2020)

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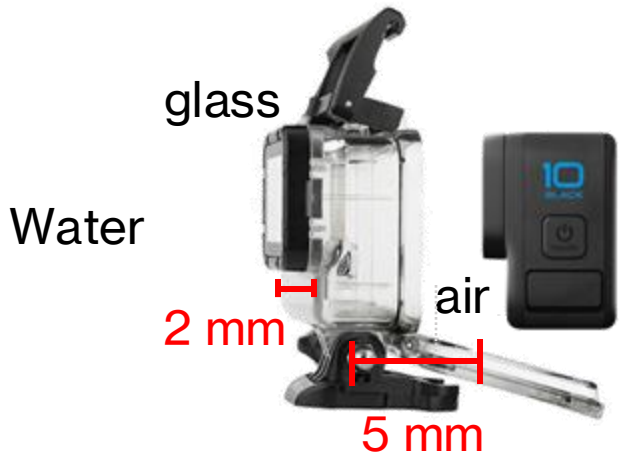
Experiment

Camera System



GoPro 10 HD, Video:
Footage+IMU streams

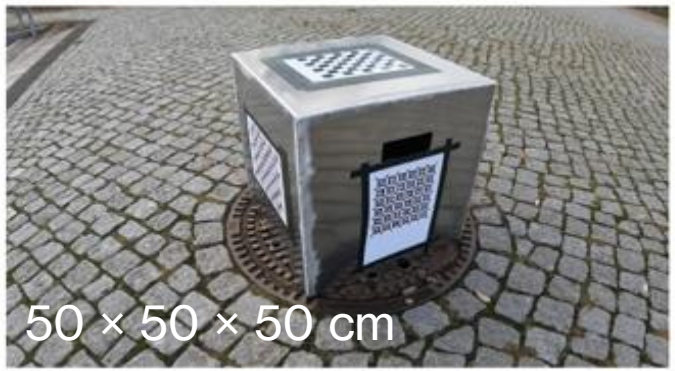
Rubik In-Air

Rubik Underwater

Shipwreck In-Air

Shipwreck Underwater

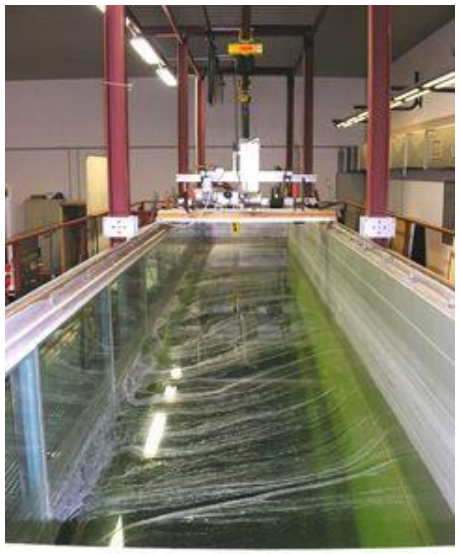
Cube In-Air



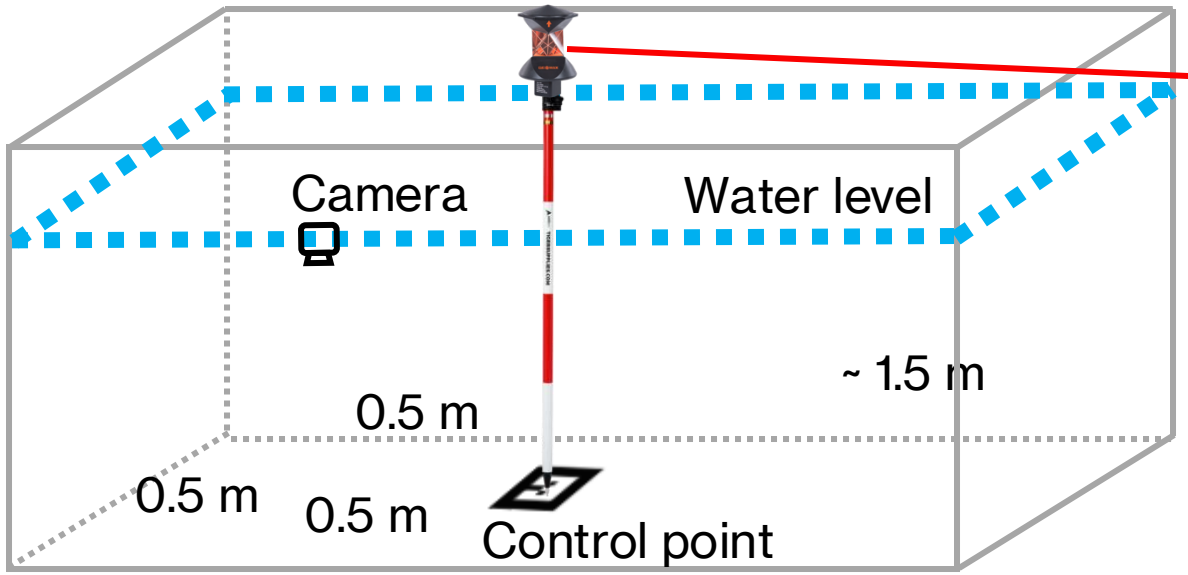
Cube Underwater

Experiment

Cube dataset



Water tank – TU Berlin ILS



Total station

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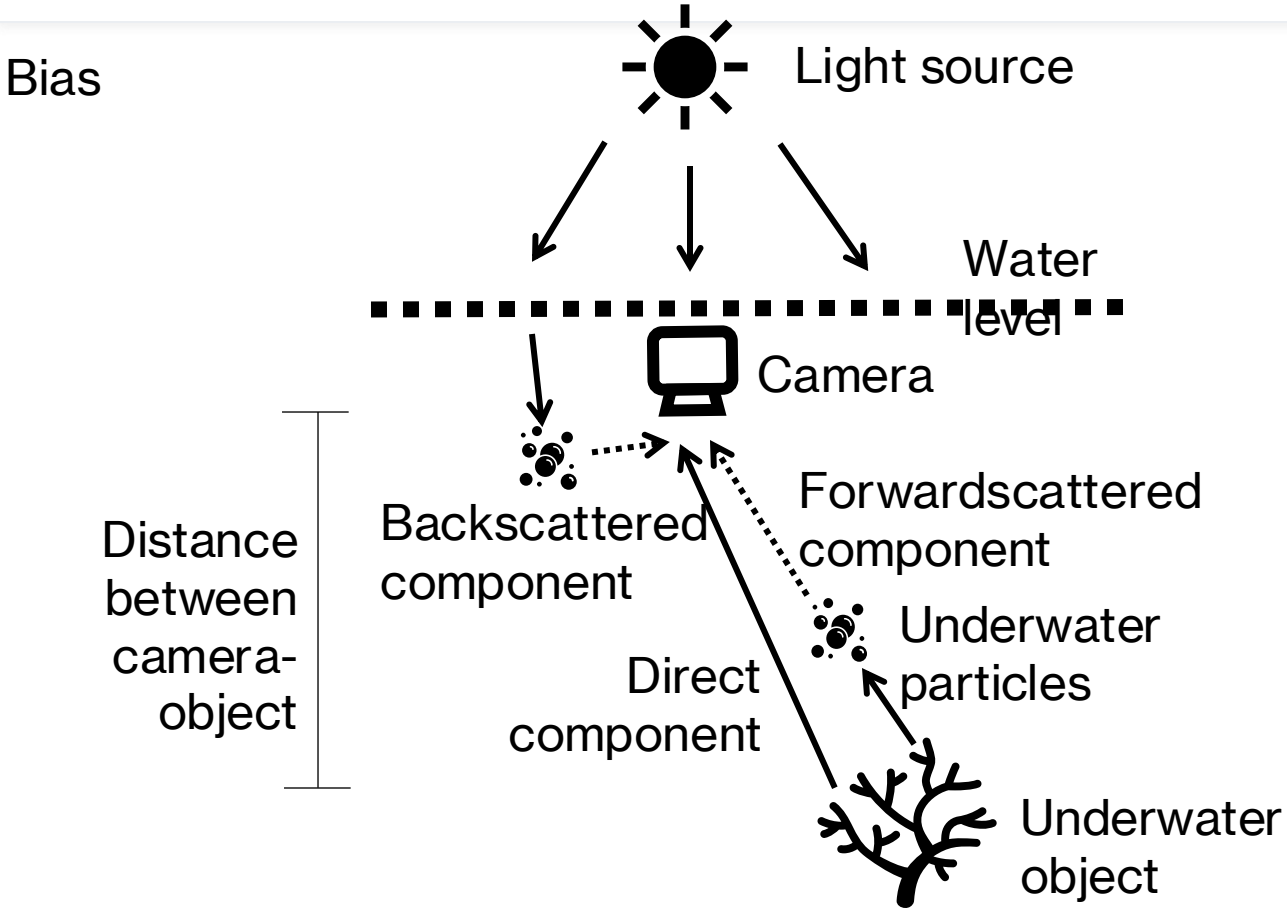
Challanges



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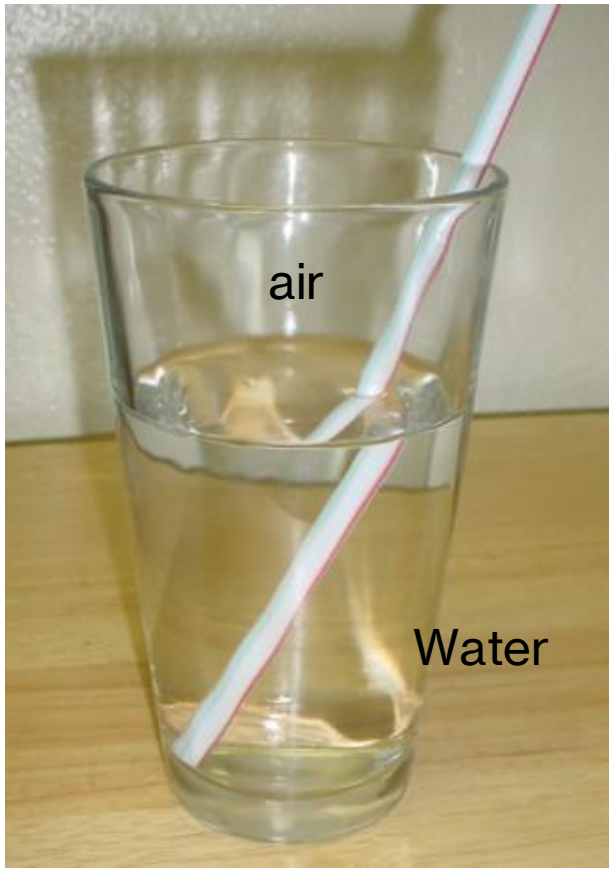
Challanges

Refraction



Dome-port

- Full field of view
- More complex calibration

Flat-port

- Cropped field of view
- Calibration based on snell's law of light propagation

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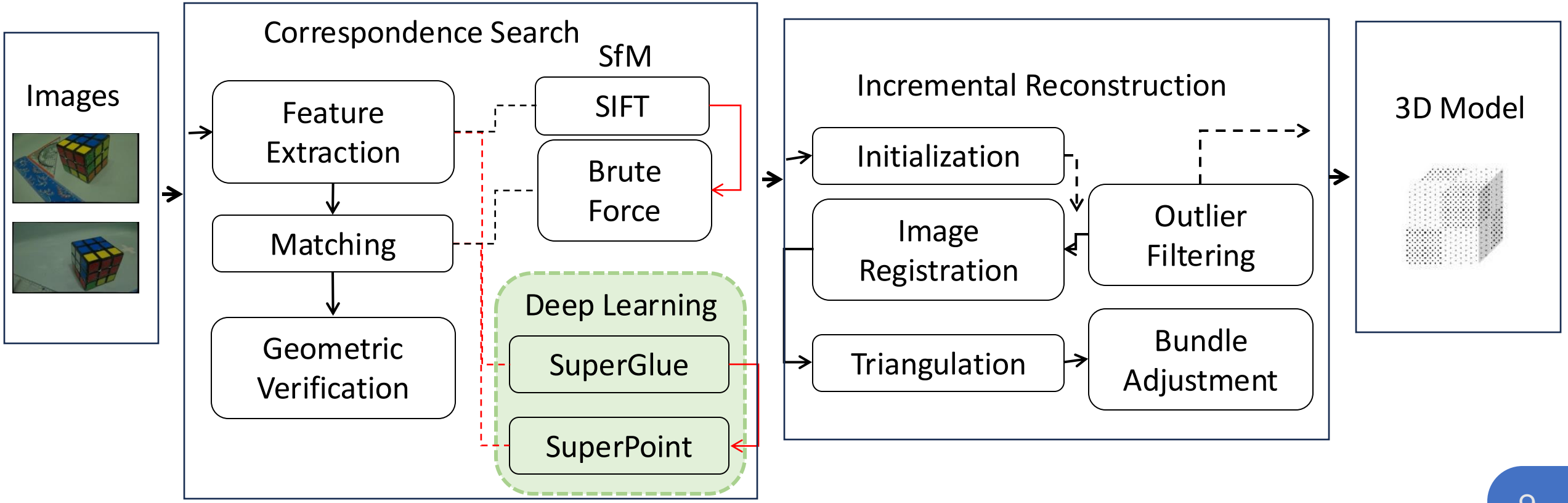
Adaptation

Deep Learning: Hierarchical Localization



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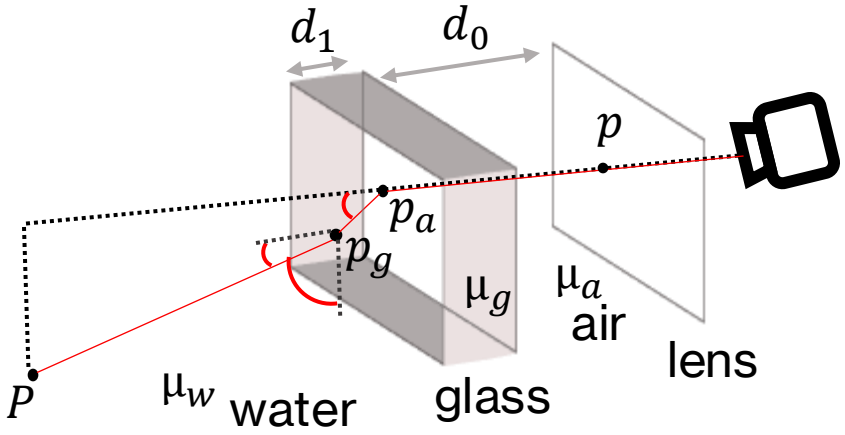
Adaptation

Refraction correction:
flat port glass



- Indirect
  - Pinhole+Axial (Pinax) camera model
  - CONSTRUCTOR UNIVERSITY
  - Łuczyński et al (2017)
- Direct
  - Colmap Underwater (Refractive Colmap) + Calibmar
  - C | A | U Christian-Albrechts-Universität zu Kiel
  - She et al (2024)

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Adaptation

Gaussian Splatting (GS)

- Fast photo-realistic modelling

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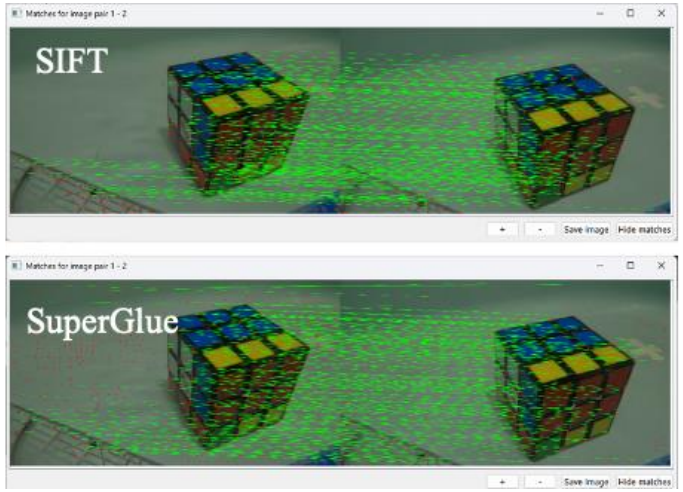
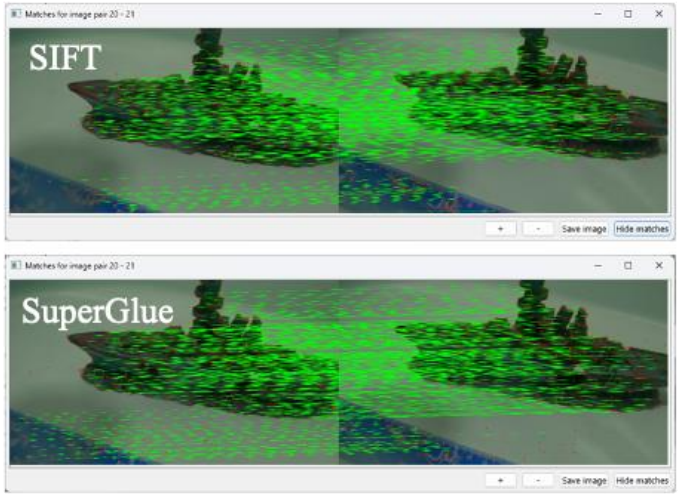
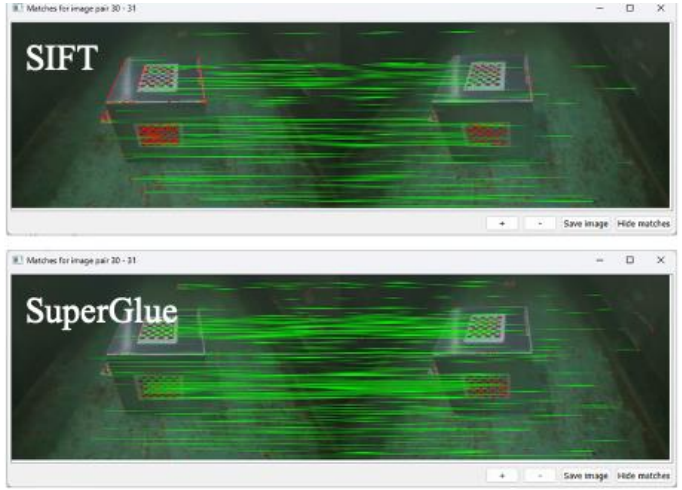
Results







Feature matching

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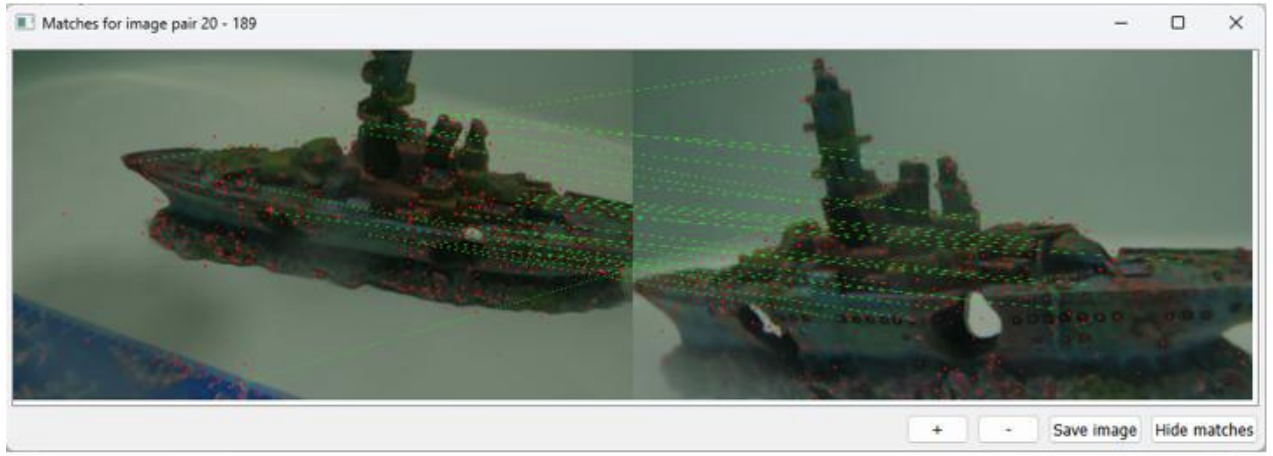
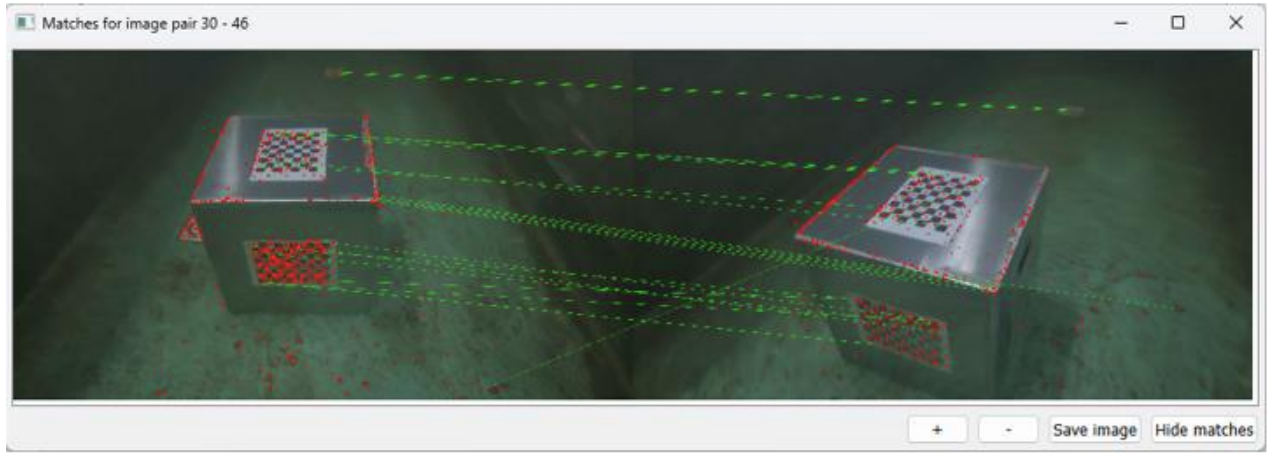
Results

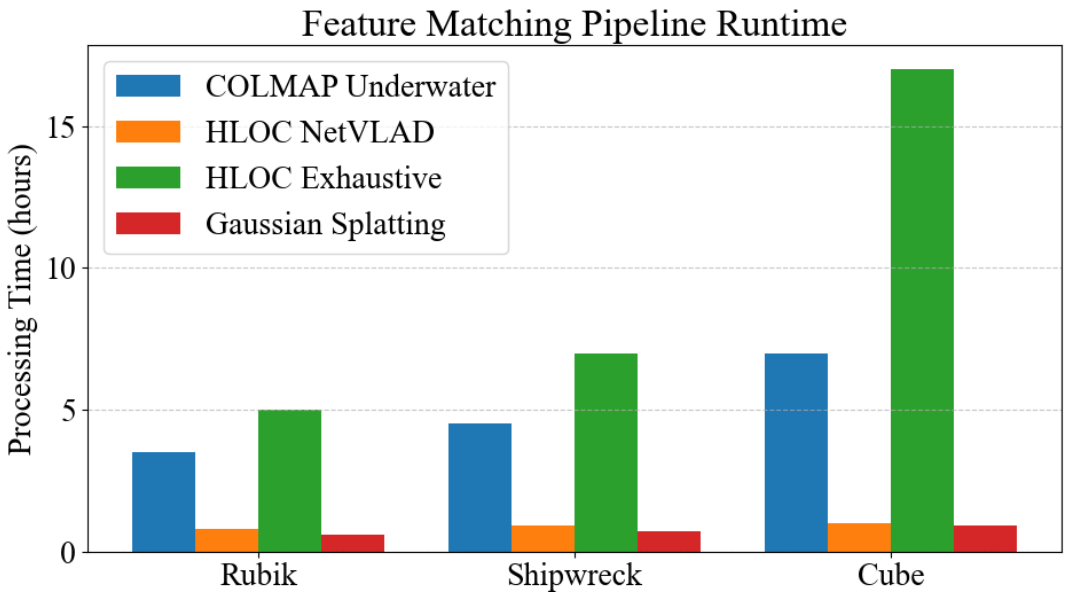
Mismatched feature points

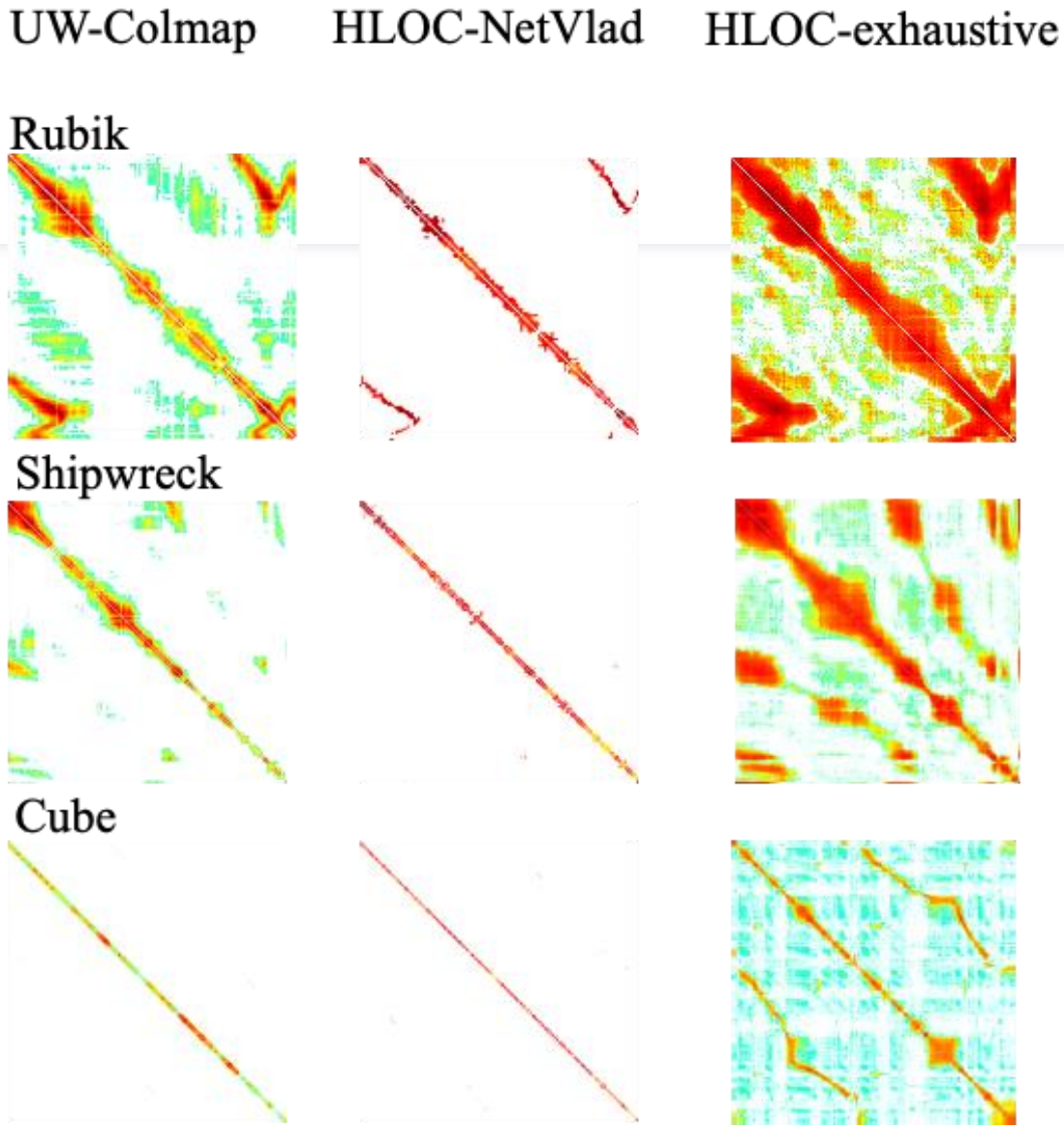




Results

Runtime and Match matrices





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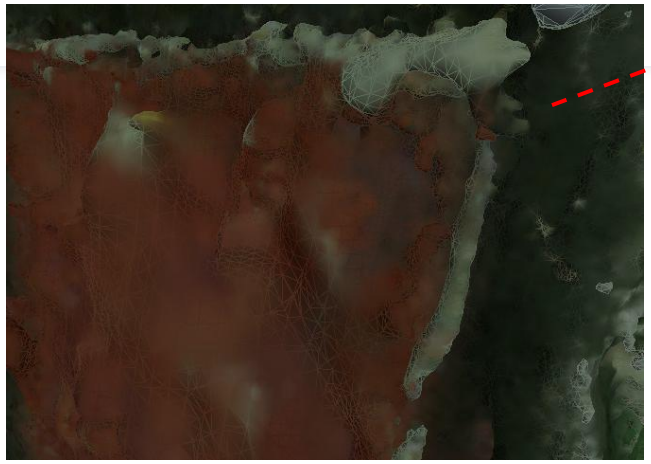
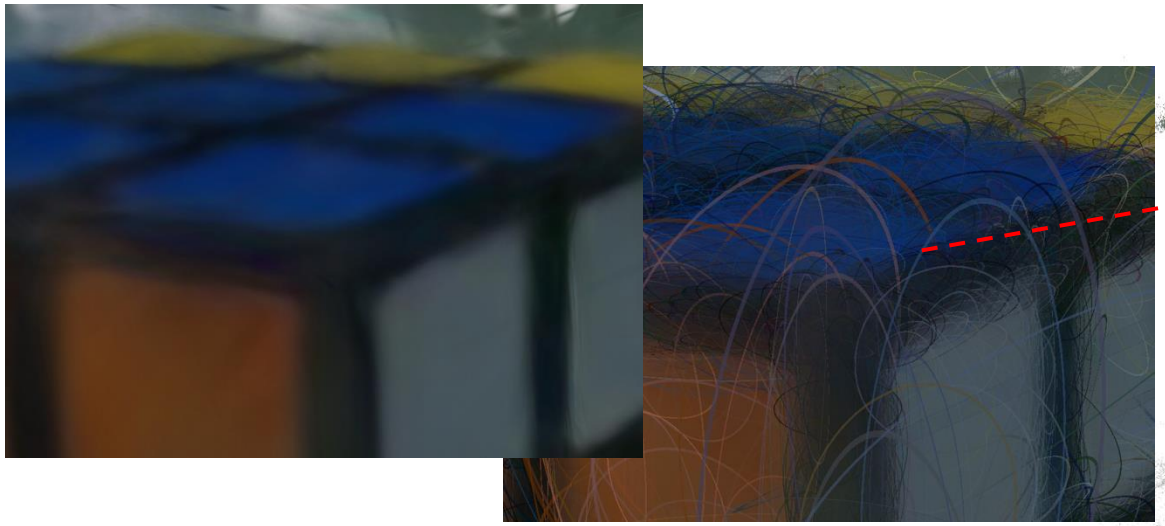
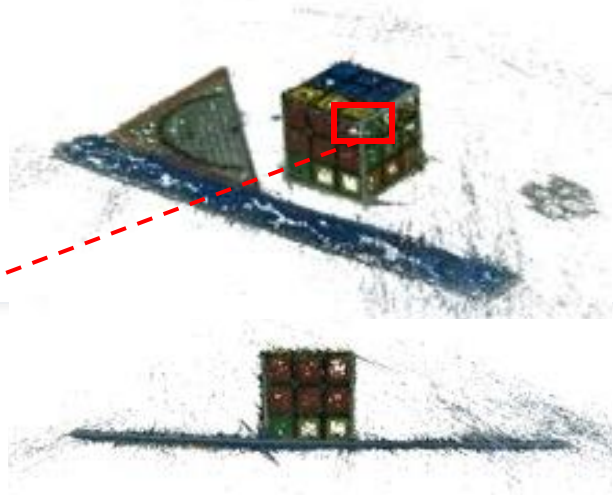
Results

Rubik dataset



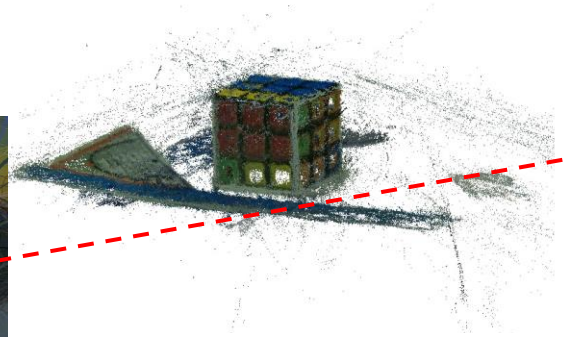


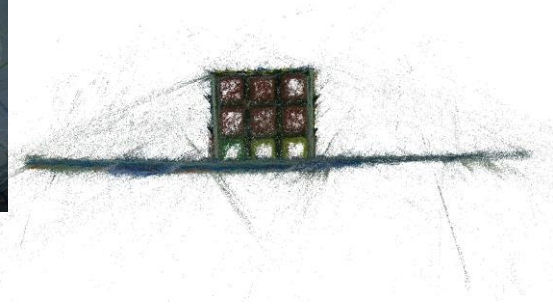
UW-Colmap



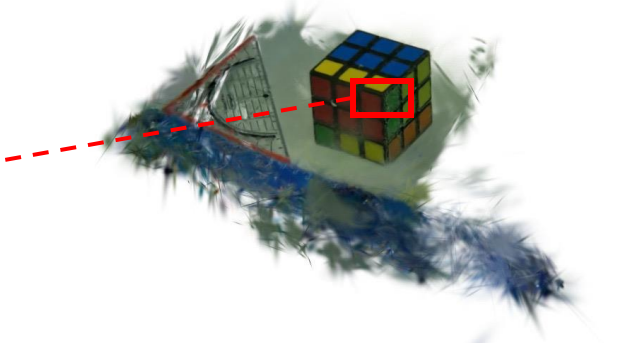
HLOC

HLOC+Colmap





Gaussian Splatting



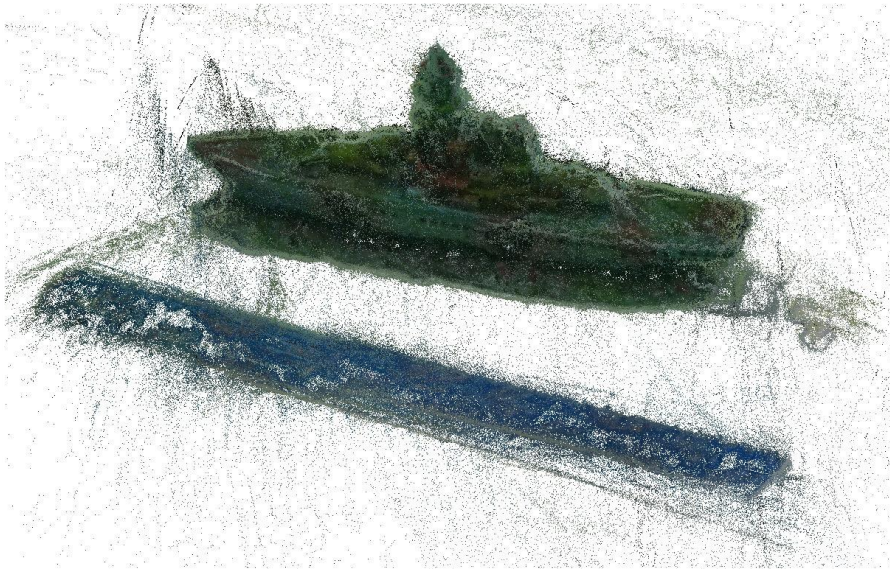
Results

Shipwreck dataset

UW-Colmap

HLOC

HLOC+Colmap



Gaussian Splatting

Results

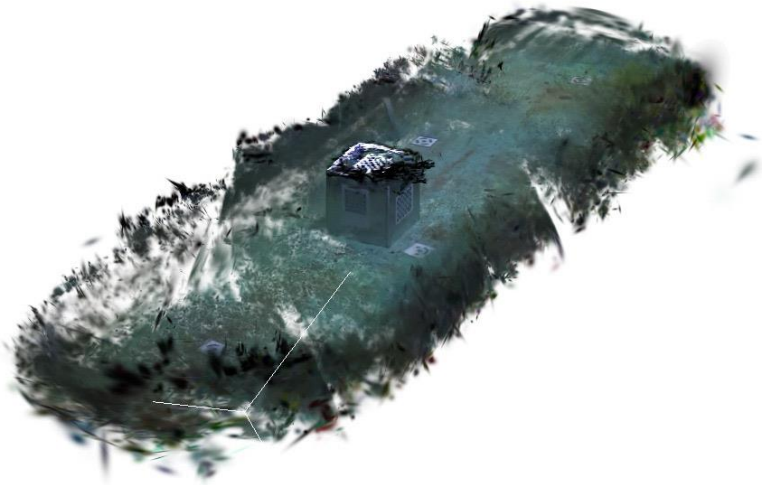
Cube dataset

UW-Colmap

HLOC

HLOC+Colmap

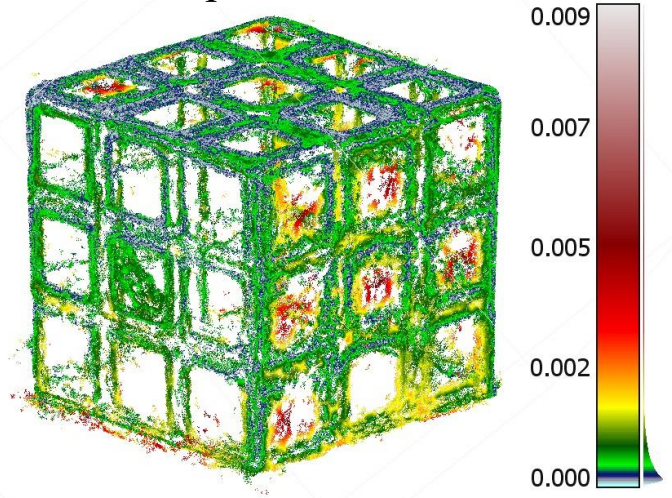
Gaussian Splatting



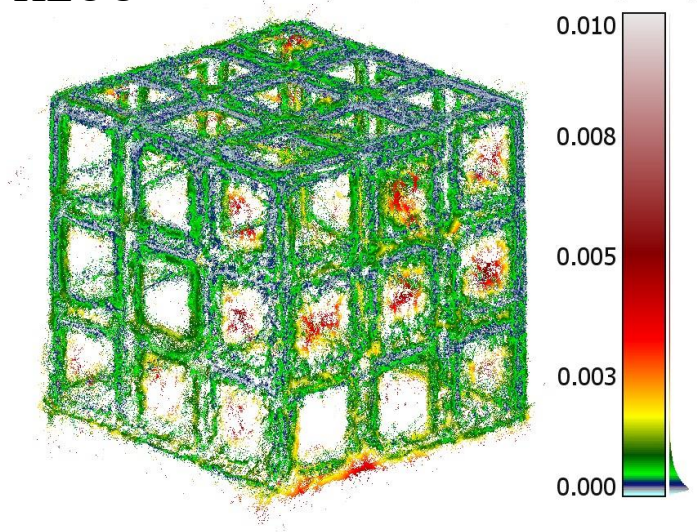
Results

Rubik dataset

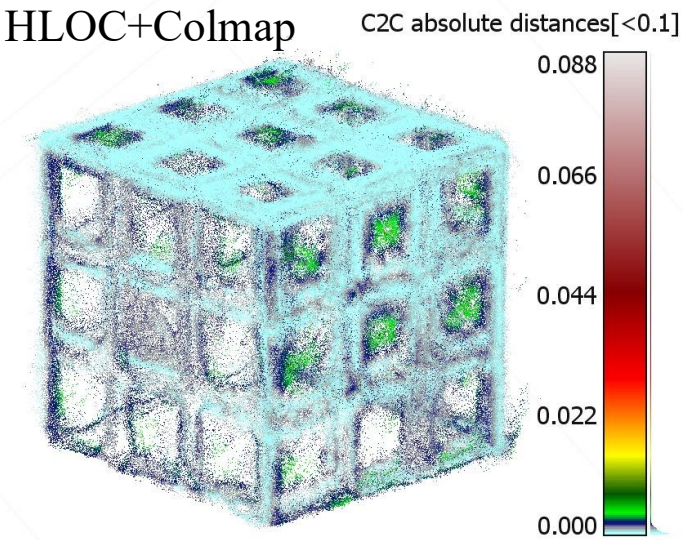
UW-Colmap



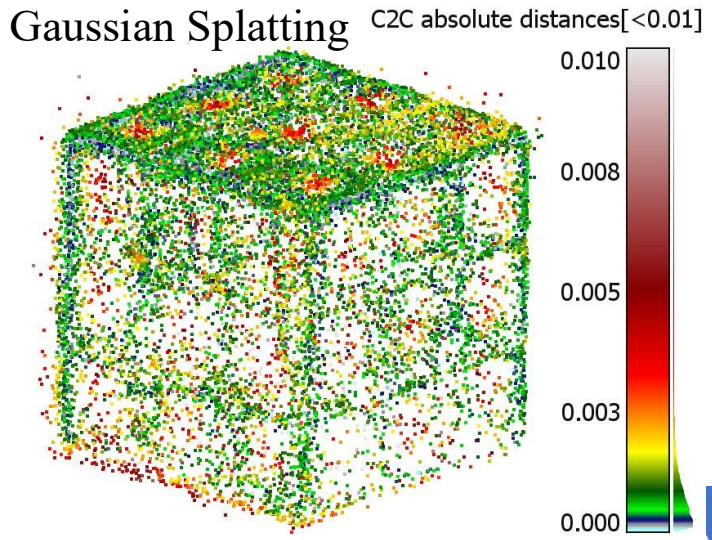
HLOC



HLOC+Colmap



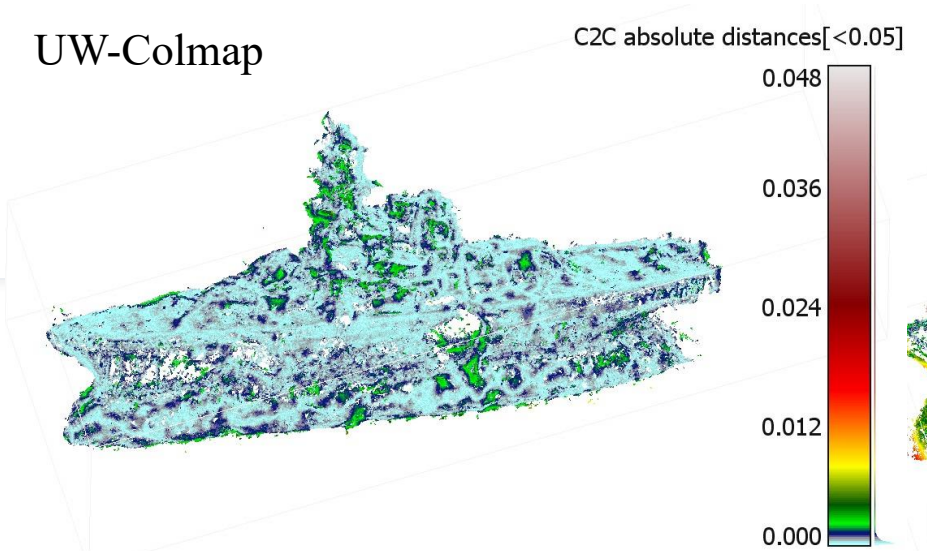
Gaussian Splatting



Results

Shipwreck dataset

UW-Colmap



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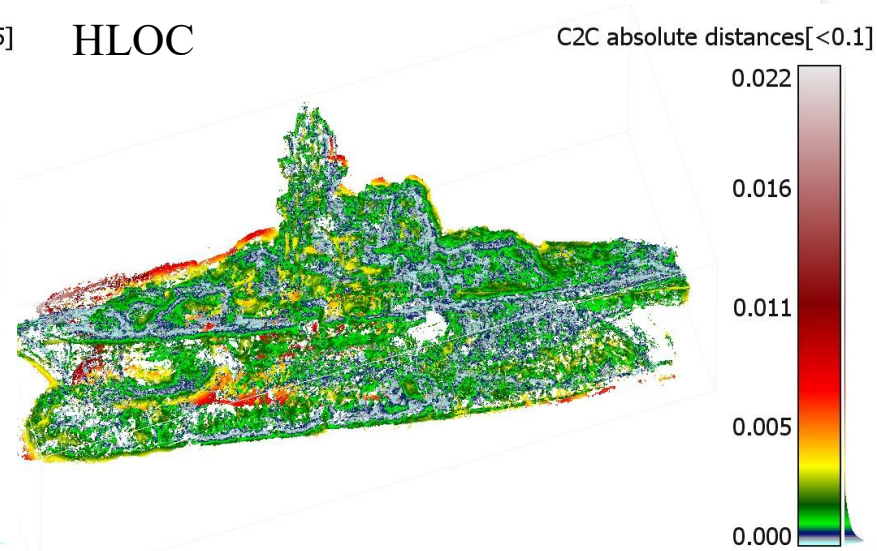
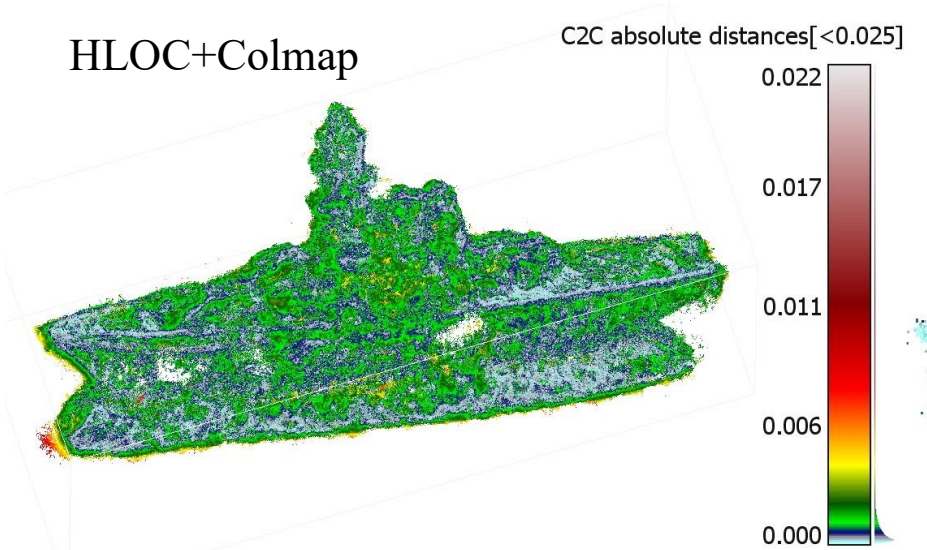
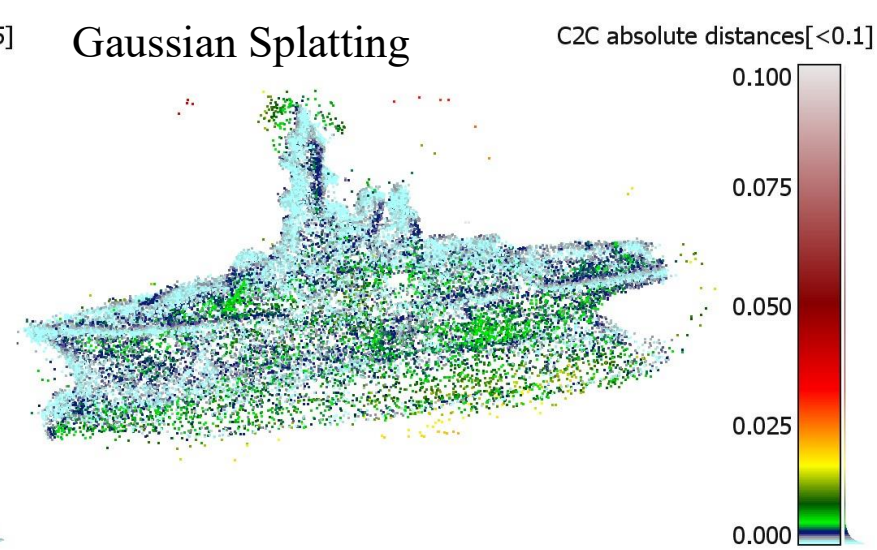


HLOC+Colmap

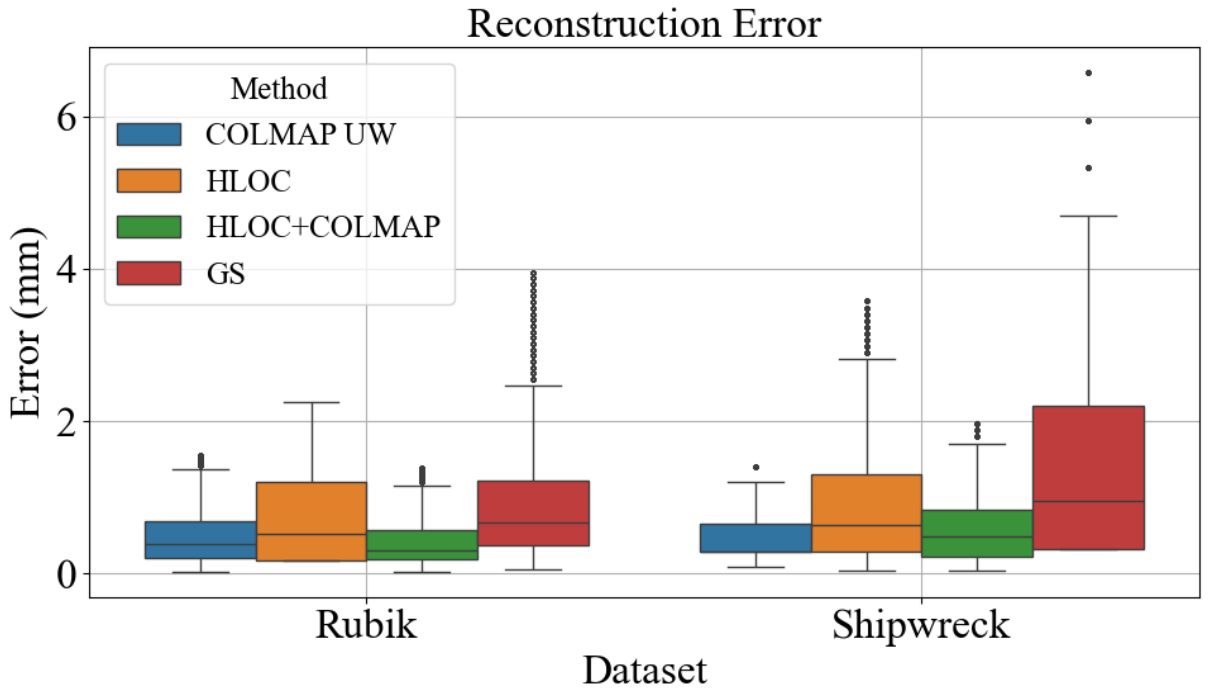


Gaussian Splatting



Results

- Colmap UW produces highest accuracy
- HLOC has more noisy model, hence larger error
- GS tends to have more accumulated error (due to the more sparse points)



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Outlook

- Larger dataset → ROV shipwreck + Reef mapping
- Integration HLOC + Refraction correction
- Gaussian Splatting + Refraction correction

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Thank You

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