Opti-Acoustic Scene Reconstruction in Highly Turbid Underwater Environments

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Motivation

Scene reconstruction is an essential capability for underwater robots navigating **highly turbid water** conditions, specially while in **close proximity** to structures.

PROBLEM

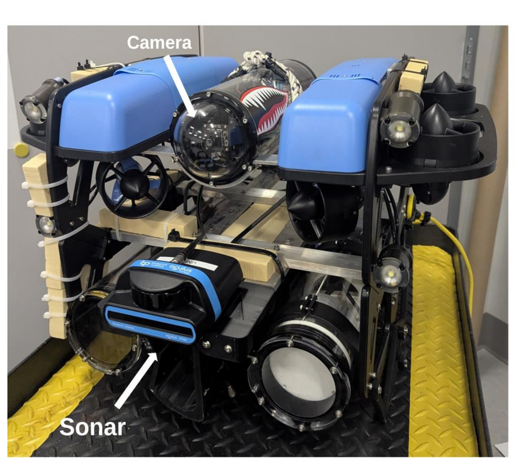
➔ **Monocular vision**-based reconstruction methods are **unreliable in turbid waters** and **lack depth scale** information.
➔ **Sonars** are robust to turbid water and non-uniform lighting conditions, however, they have **low resolution** and **elevation ambiguity**.

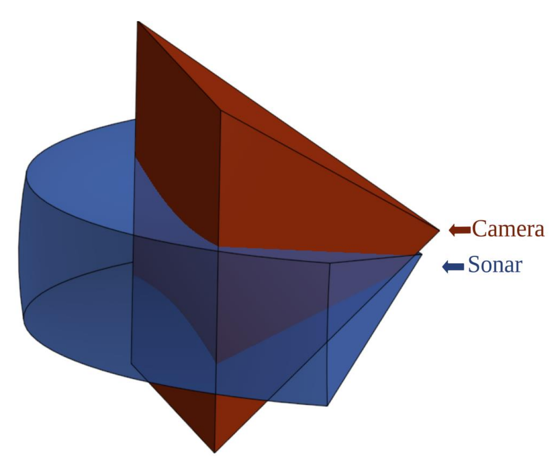
GOAL

Provide a scene reconstruction method that:
➔ Merge sonar and monocular camera without assuming the availability of reliable visual features, specially optimized to work in **turbid water**.
➔ Applicable in **diverse settings**.
➔ Suitable for platforms running in **real-time.**
➔ **Simplified approach** does not require training and contains few tuned parameters.
➔ Reconstructions from a **single pose**, eliminating the need for multi-view data.

Methodology

We assume that a robot is equipped with a **forward-looking imaging sonar** and a **forward-looking camera**, with **overlapping fields of view**.

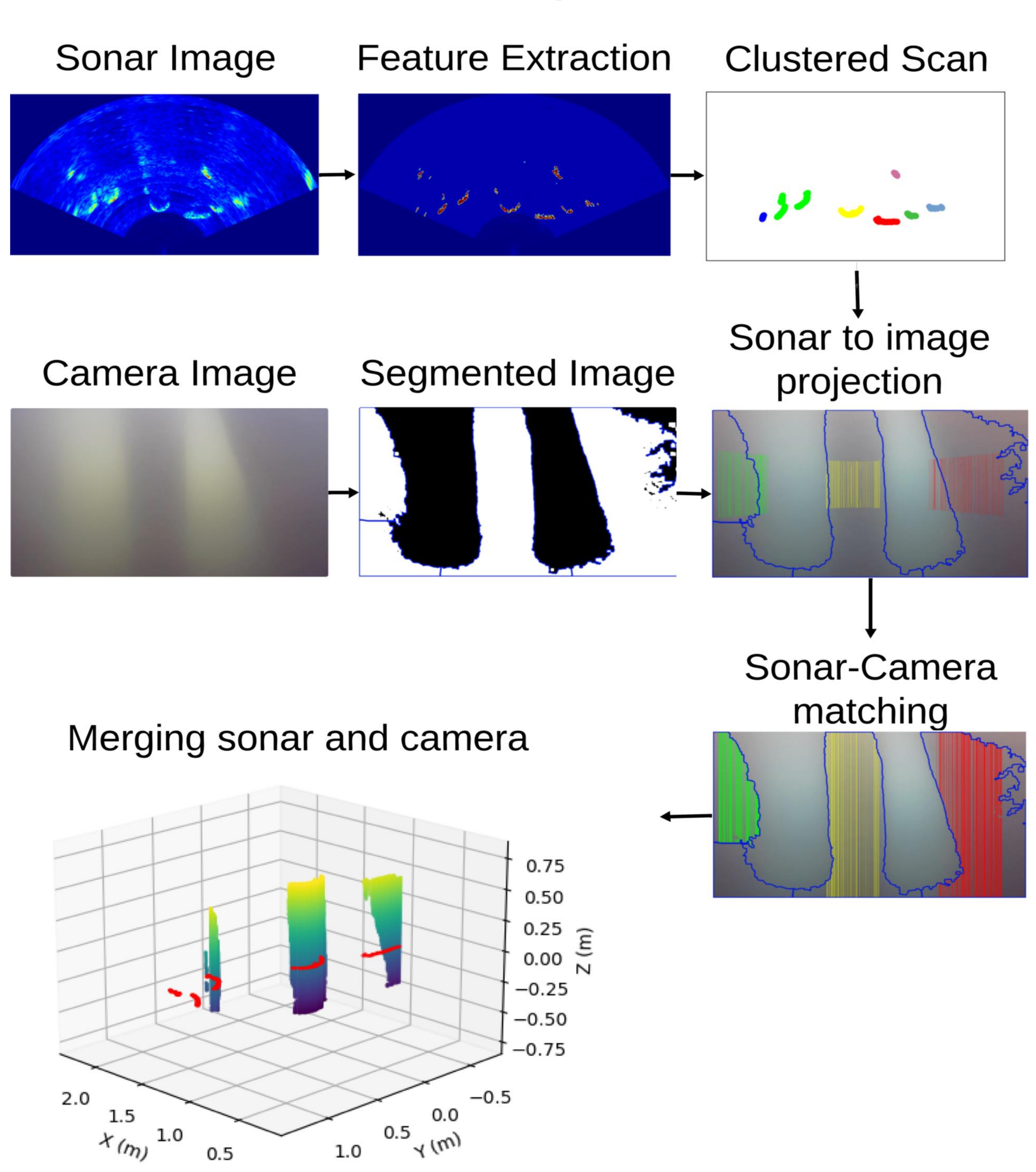




Associate range measurements from sonar with elevation measurements from optical images, leveraging their overlapping but complementary vantage points, each lacking a dimension in their respective coordinate frames.

➔ **Distance** is derived from the original **sonar return**
➔ **Elevation** is determined by the **optical image**

General Pipeline



Conclusion

Performance against state-of-the-art techniques across various turbidity levels, demonstrate **comparable accuracy** while maintaining **robust coverage** of reconstructed environments. In addition, field tests highlight our method's capability to recreate human-made structures with varying cross-sections in highly turbid settings.

Acknowledgements

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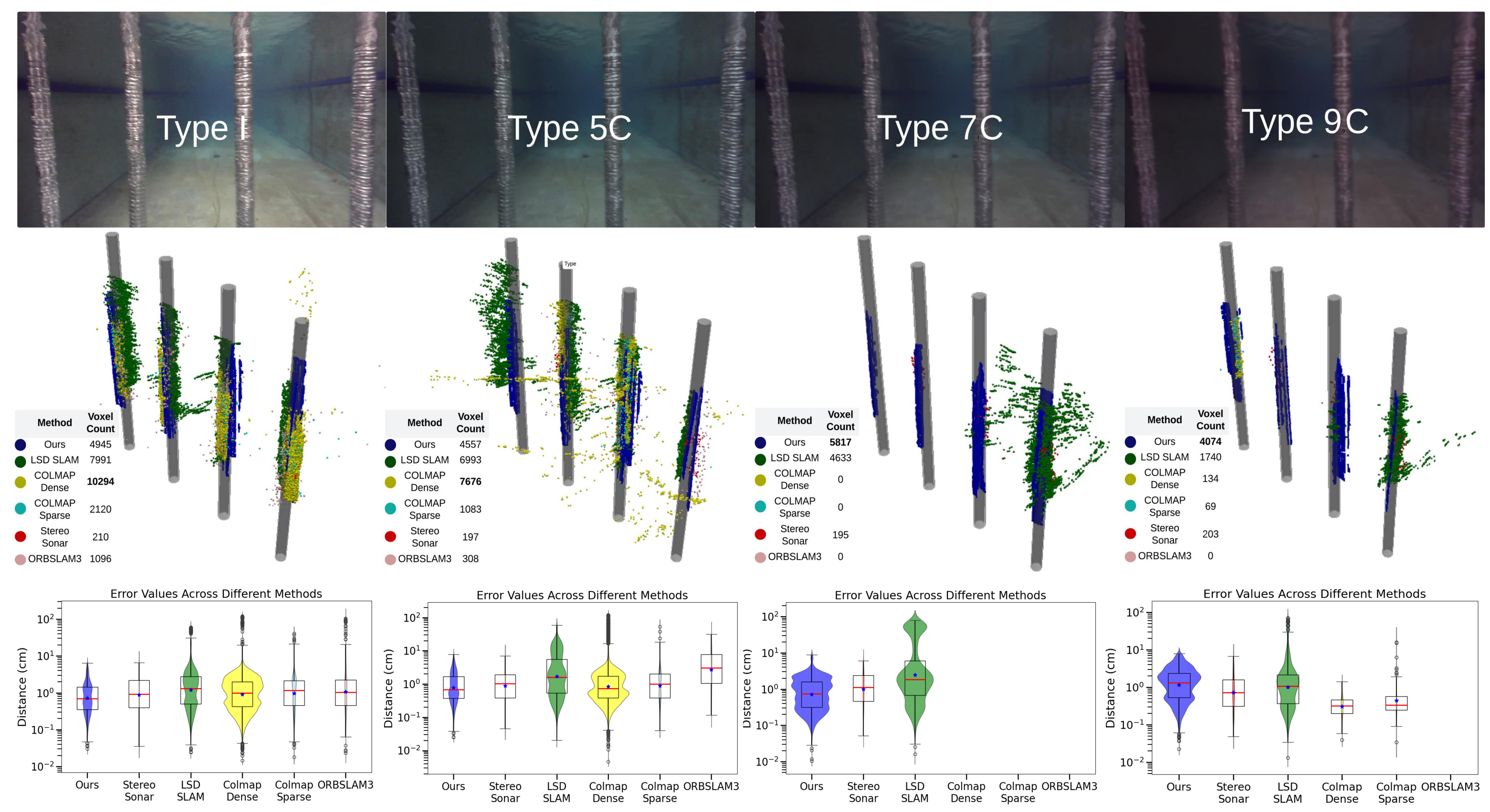
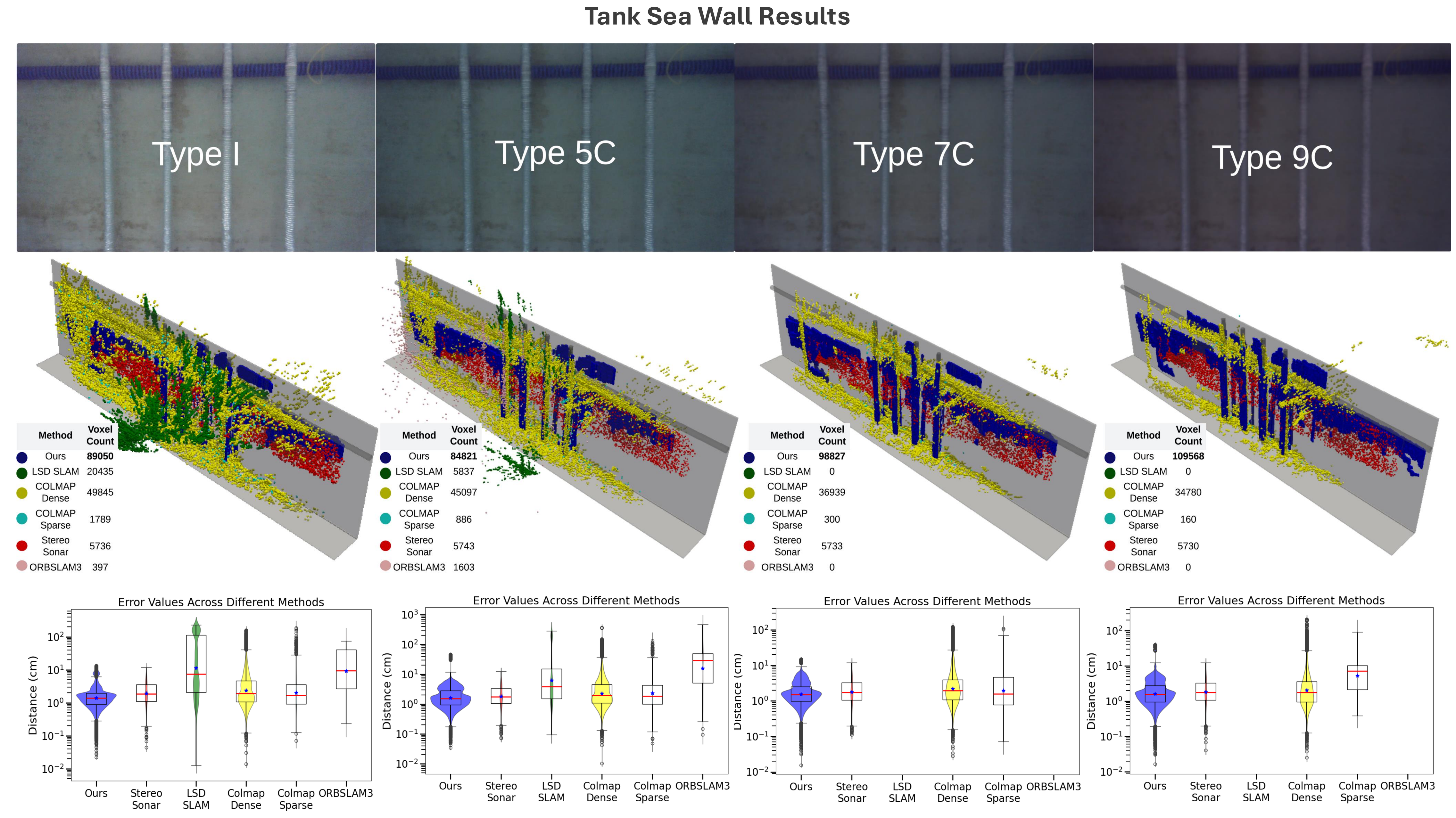
Tank Results

Reconstruction results in different types of water.
Each column in the image shows results for a specific water type.
Top row: example images of original tank water (Type I) and other emulated water types.
Middle row: ground-truth CAD model in gray, with different colored point clouds depicting each algorithm outputs. This row also shows the coverage of each algorithm expressed as voxel count.
Bottom row: absolute distance error values and error value distributions.

Tank Pier Pilings Results



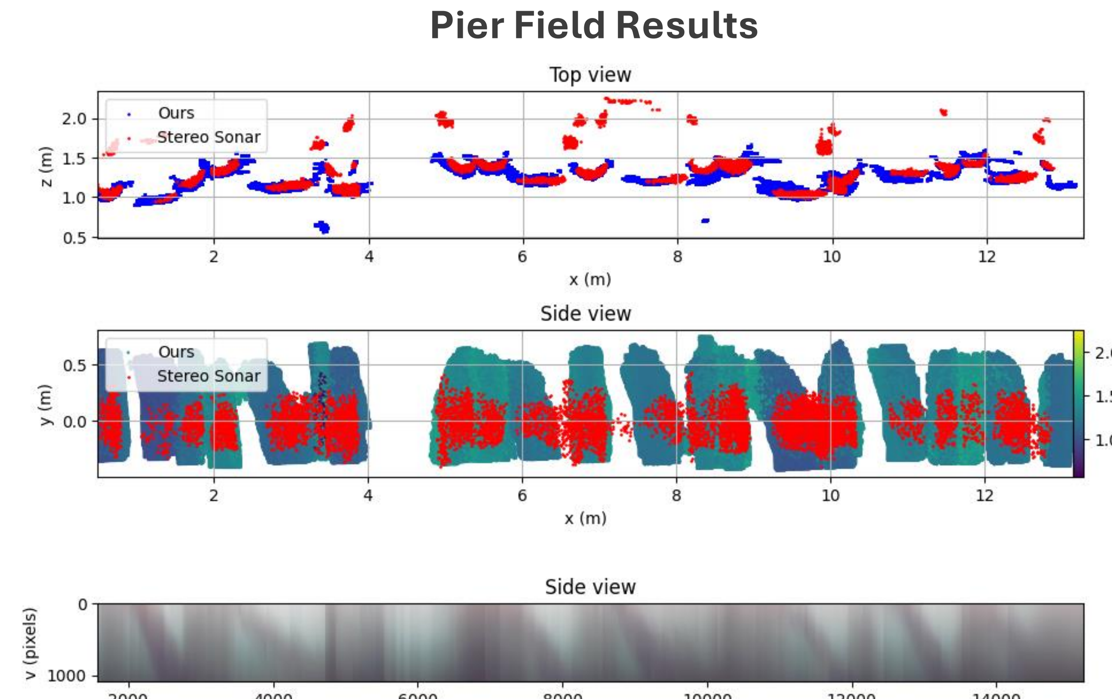
Tank Sea Wall Results



Field Results

Field experiments conducted at the United States Merchant Marine Academy (USMMA).
The vision-based approaches (LSD SLAM,ORBSLAM3, and COLMAP) used during the tank experiments were not capable providing a resulting reconstruction.
Top two rows: reconstruction results.
Bottom row: unscaled optical data.

Pier Field Results



Sea Wall Field Results