On the Mutual Relation between SLAM and Image Enhancement in Underwater Environments

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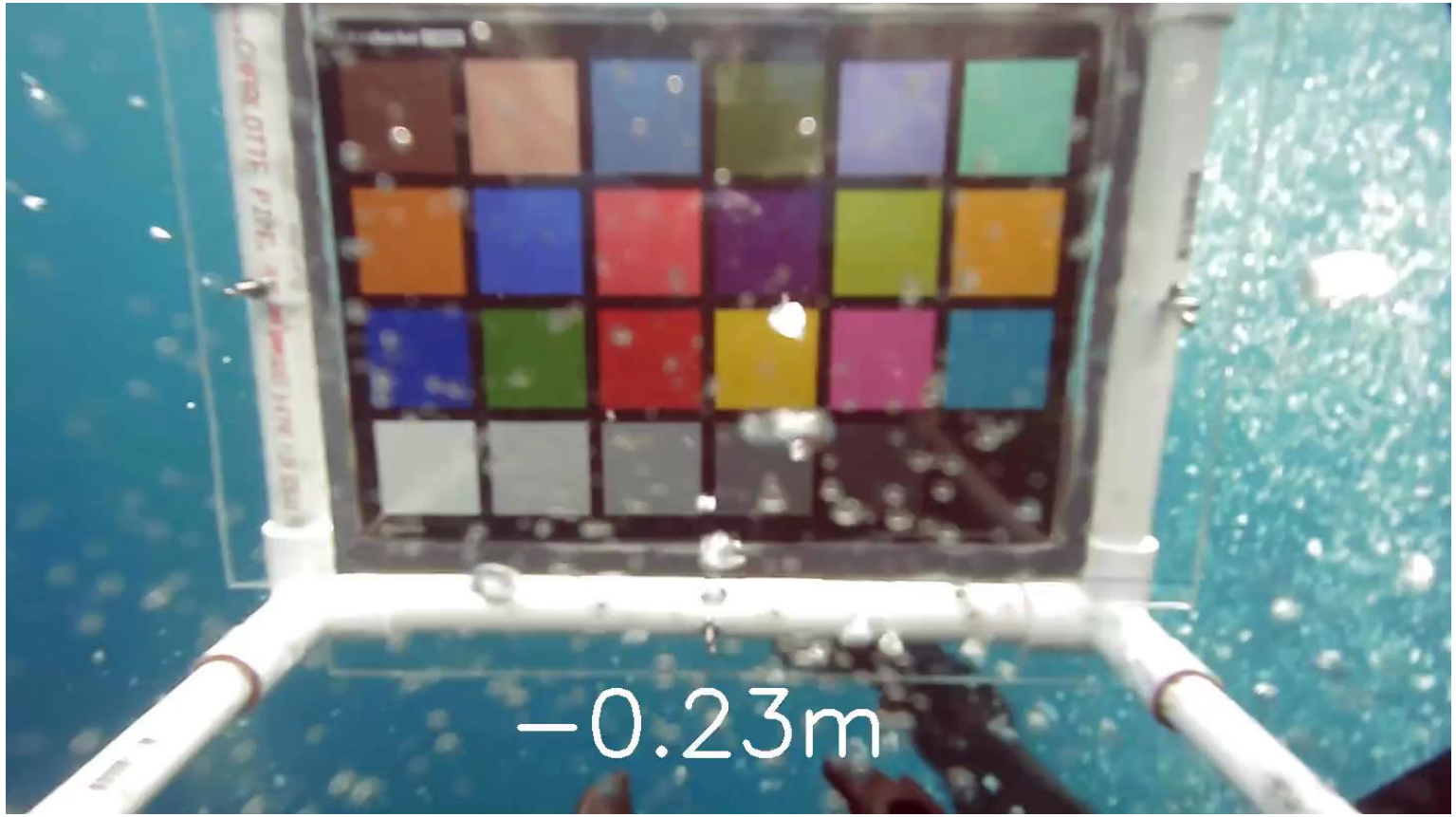
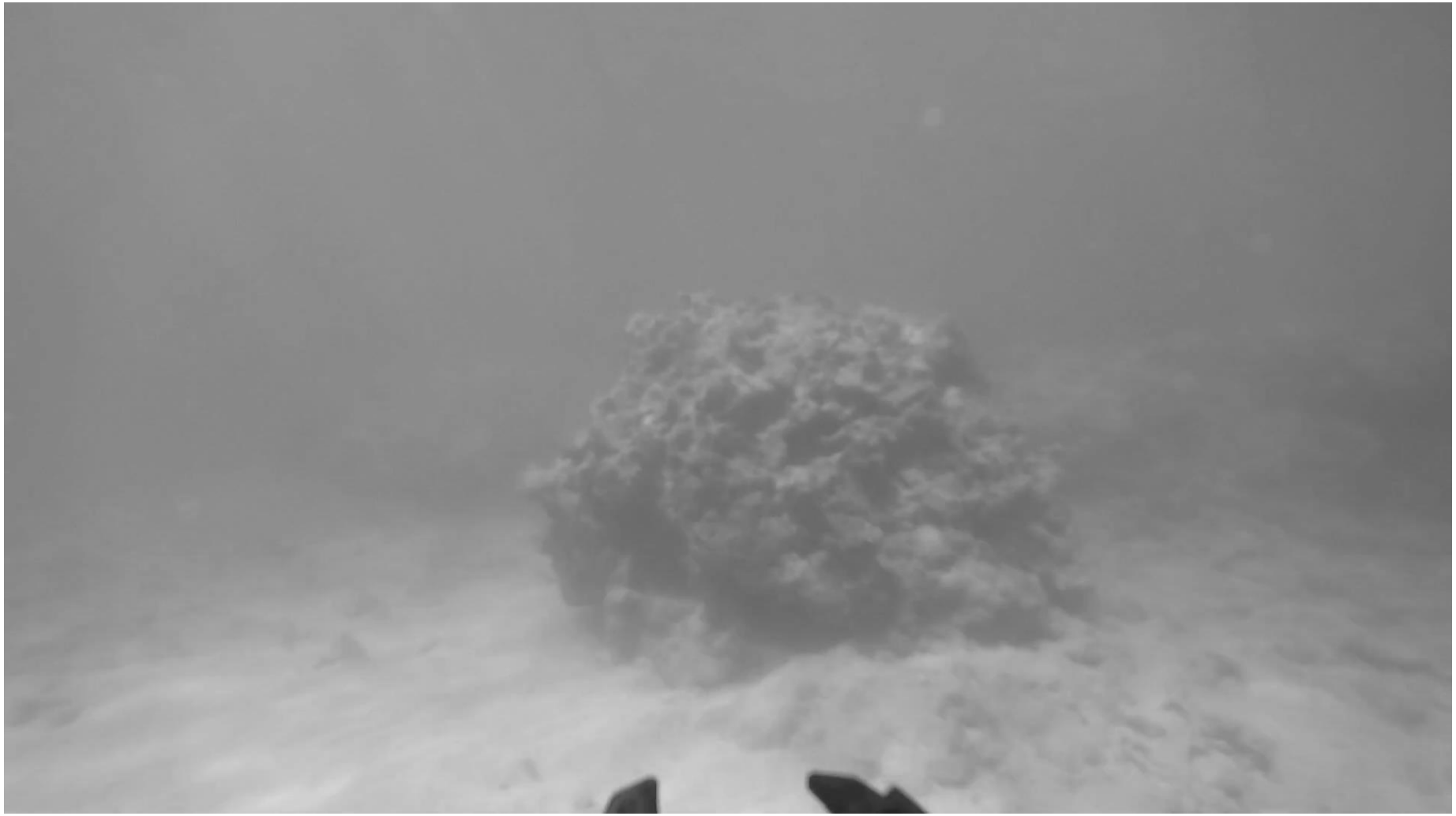
Underwater Exploration

- Low-cost ROVs and AUVs
  - Monocular camera
  - Noisy, low-frequency IMU
- SLAM uncertainty
- Poor underwater perception

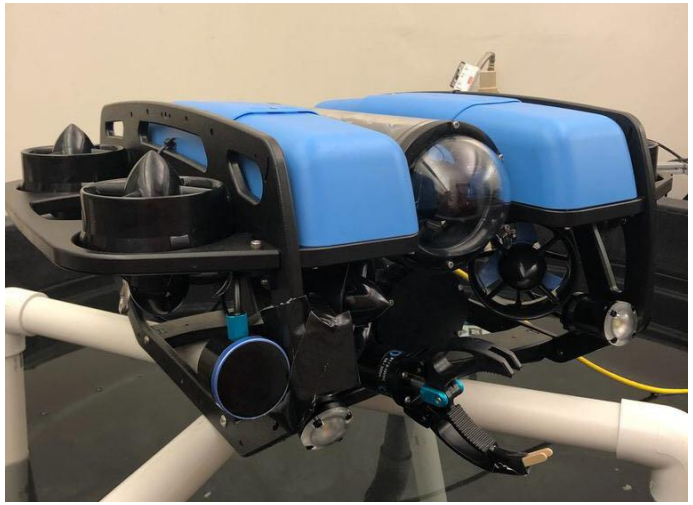
Color Degradation Over Depth



ORB-SLAM



Problem Statement



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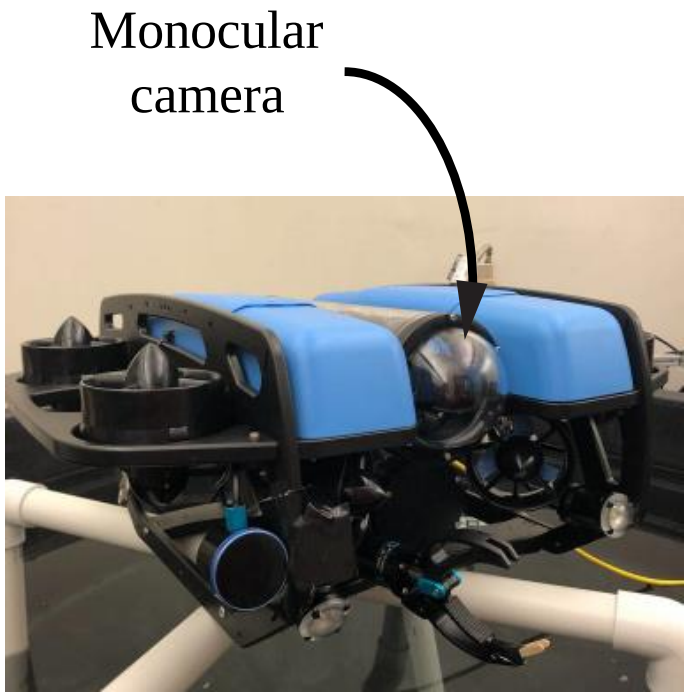

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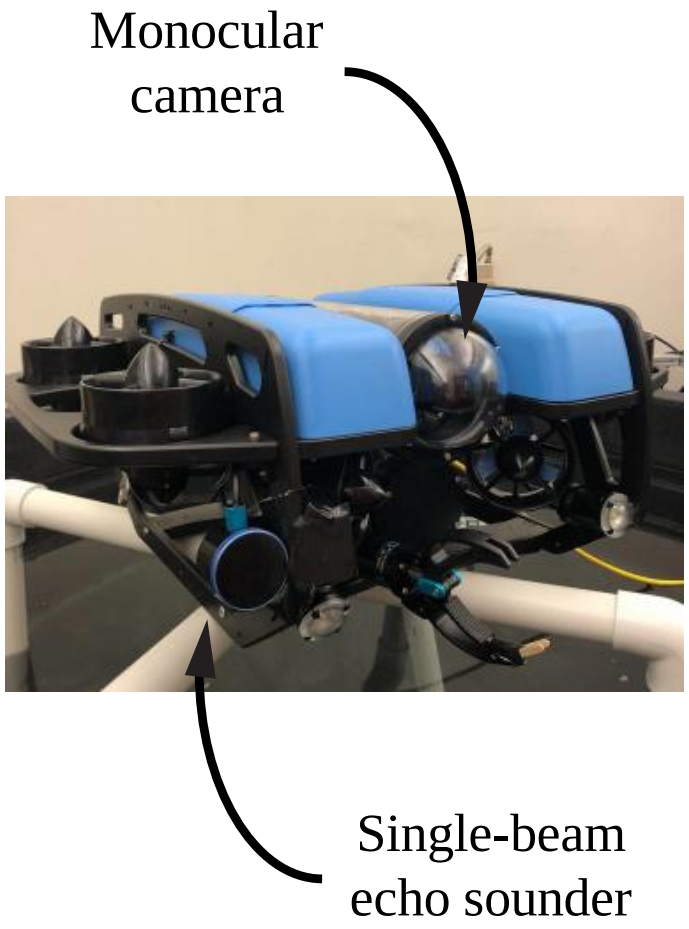

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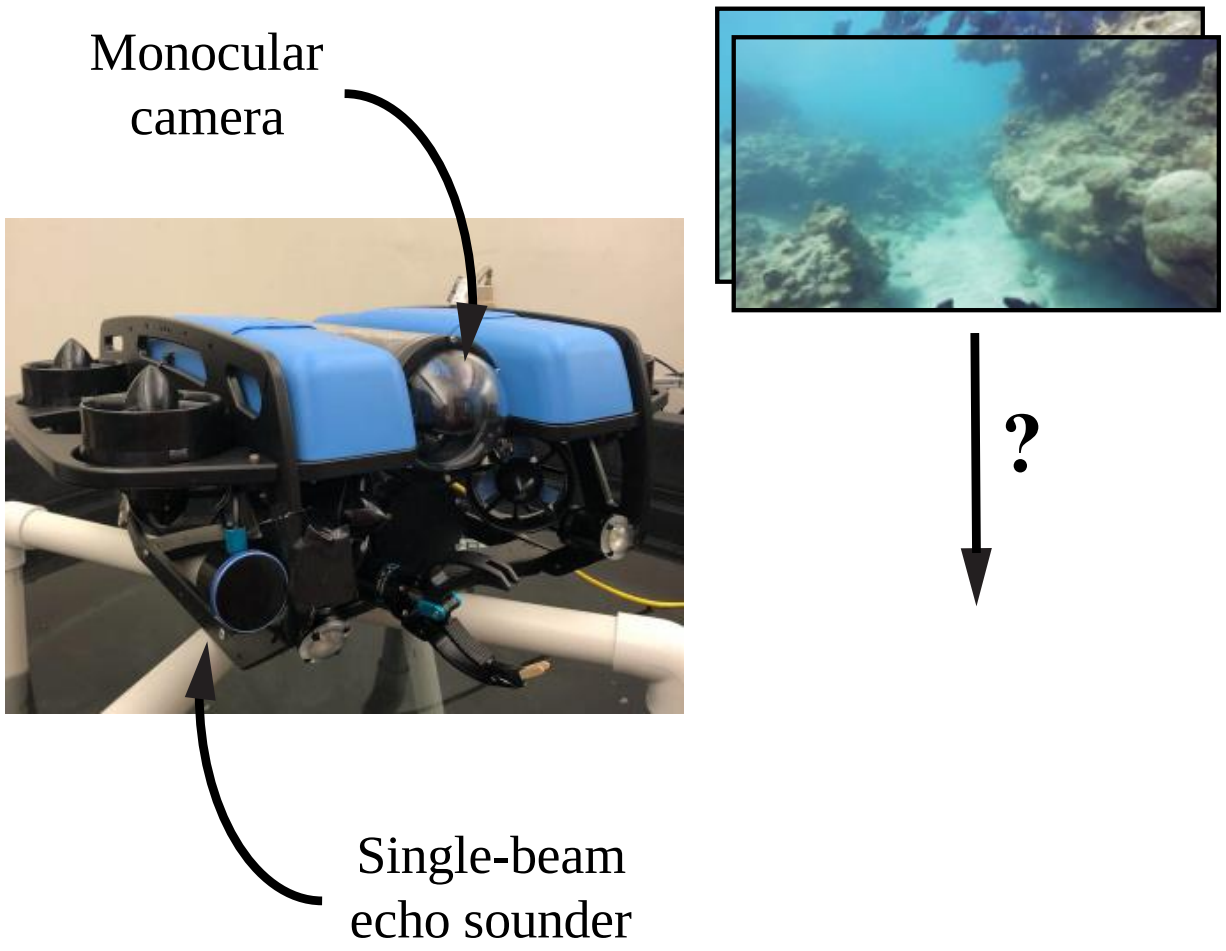

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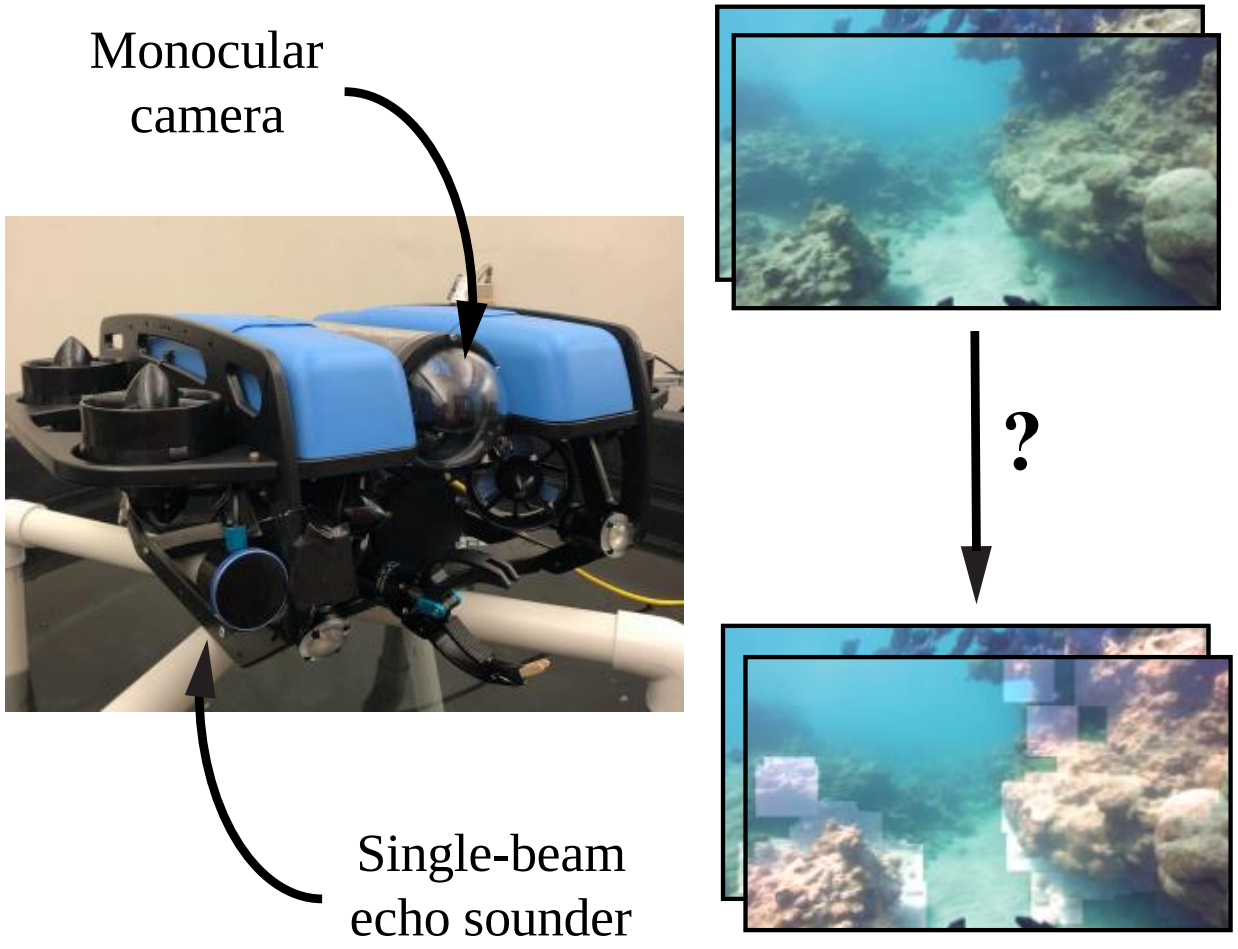
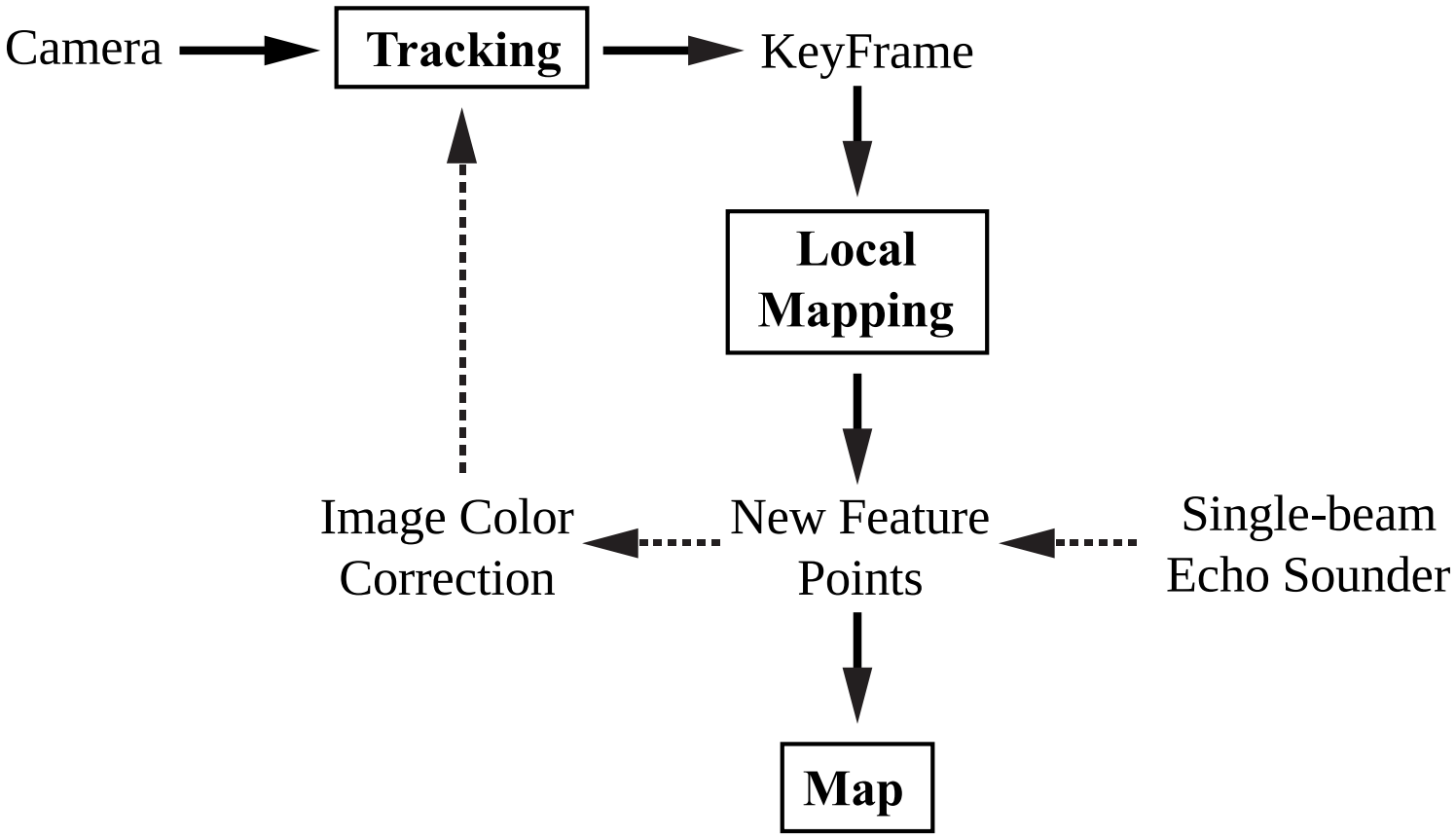


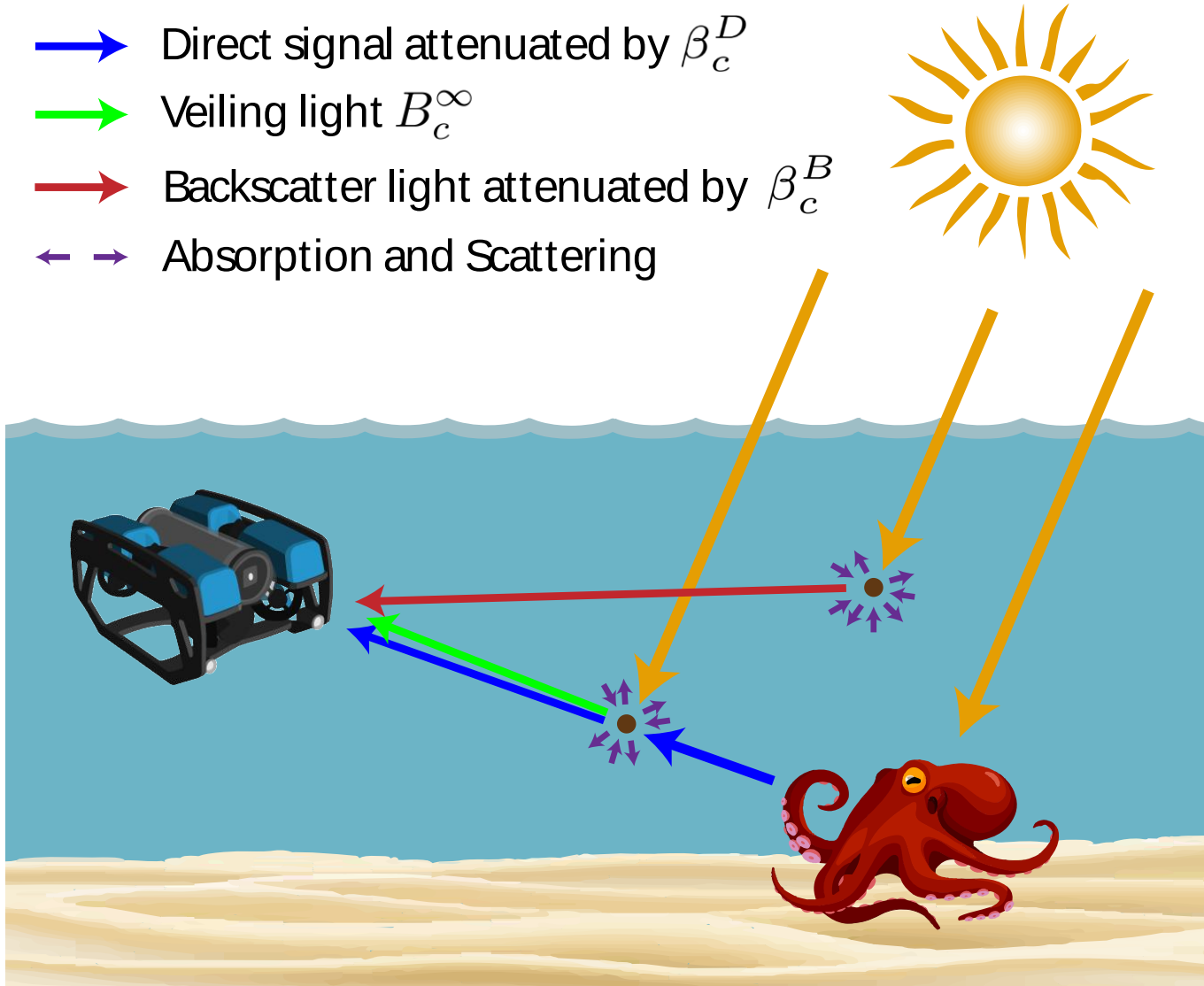
System Overview



Revised Underwater Image Formation Model

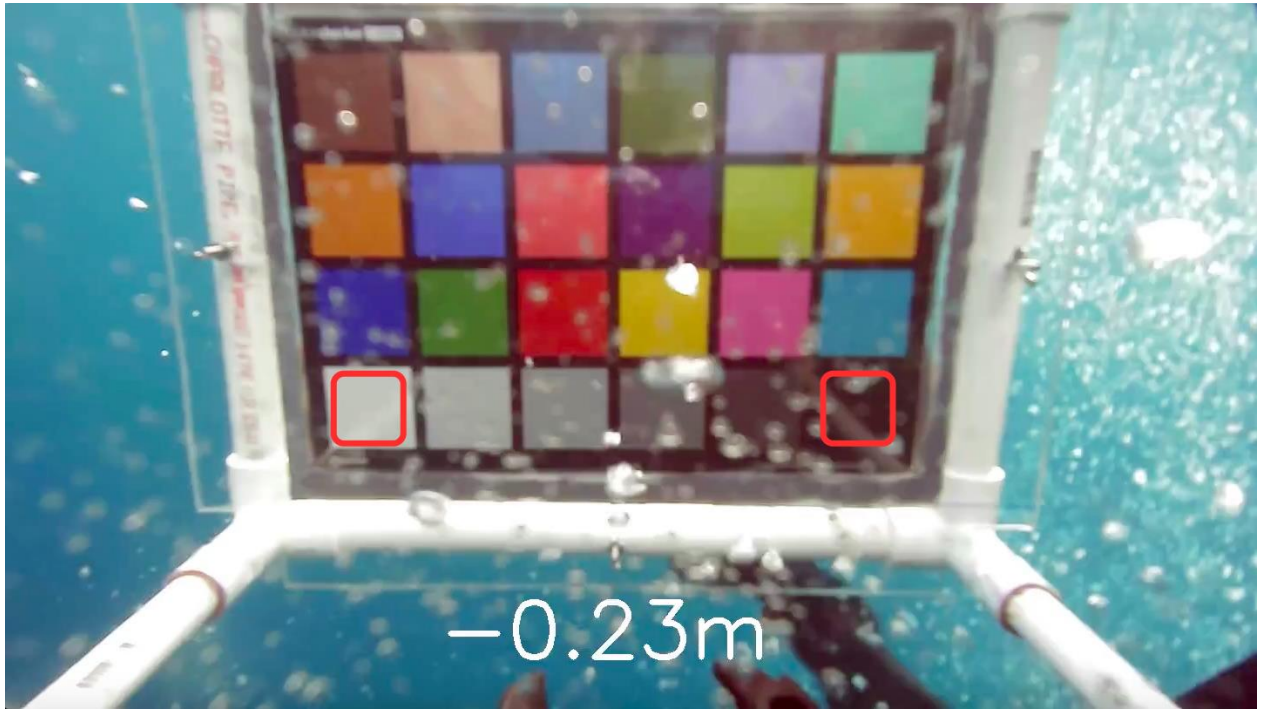
$$I_c = J_c \cdot e^{-\beta_c^D \cdot z} + B_c^{\infty} \cdot (1 - e^{-\beta_c^B \cdot z})$$

- Physics-based method
- Estimate veiling light
  - Average background color
- Estimate attenuation values



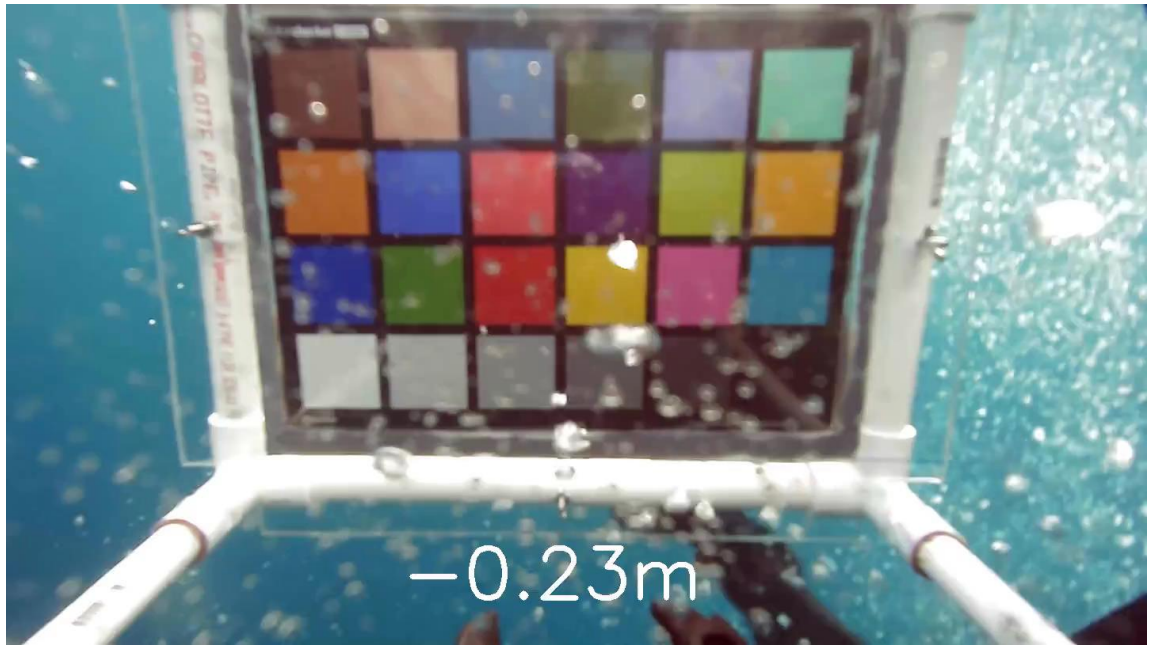
D. Akkaynak and T. Treibitz, “A revised underwater image formation model,” in Proc. CVPR, 2018, pp. 6723–6732.

Estimating Attenuation Values

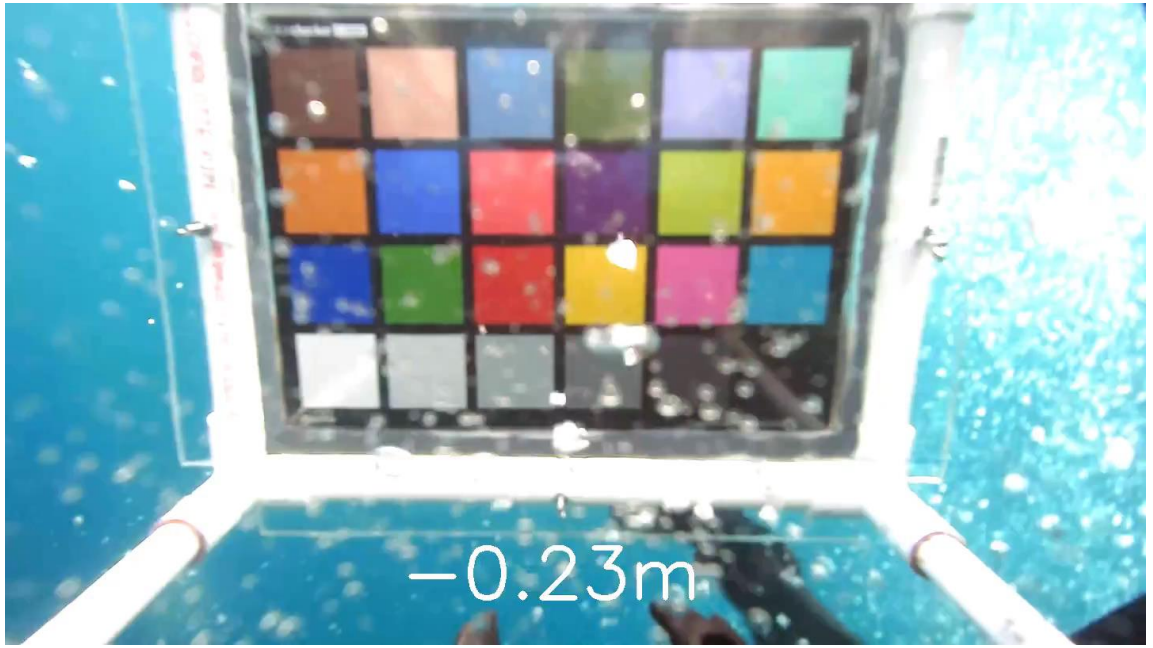


$$I_c = J_c e^{-\beta_c^D(\mathbf{v}_D)z} + B_c^{\infty}(1 - e^{-\beta_c^B(\mathbf{v}_B)z})$$

Over Depth

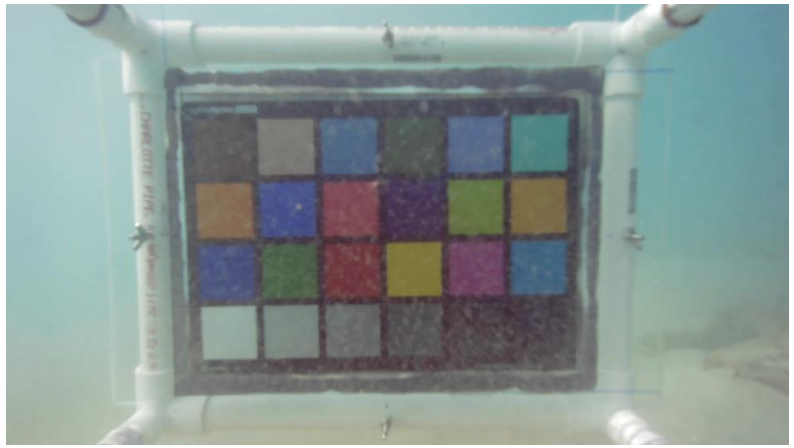
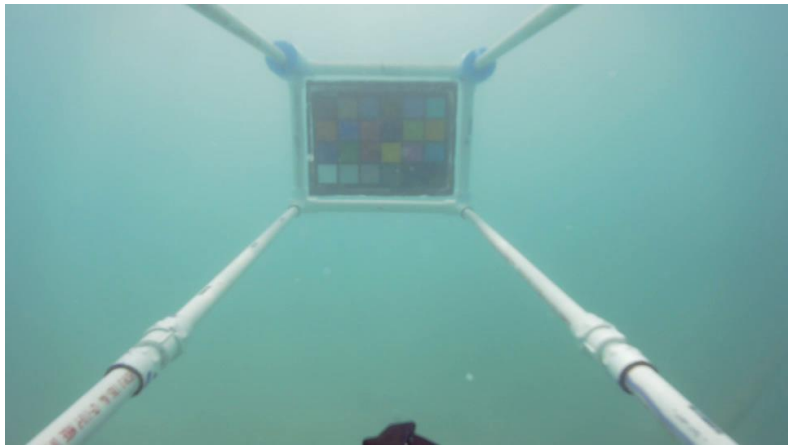


Raw

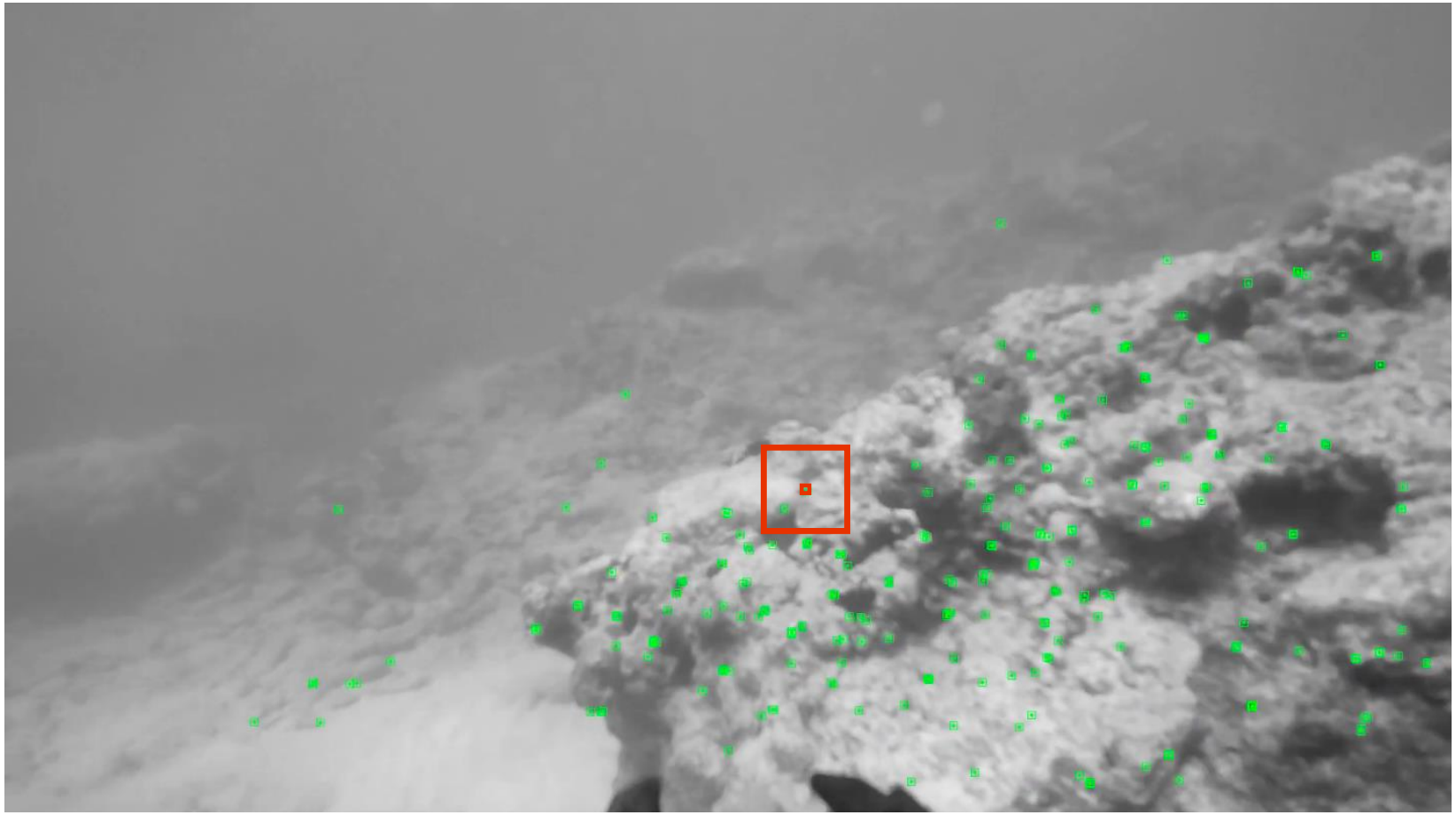


Corrected

Over Viewing Distance

	0.33 m	0.98 m
Raw		
Corrected		

ORB-SLAM Implementation

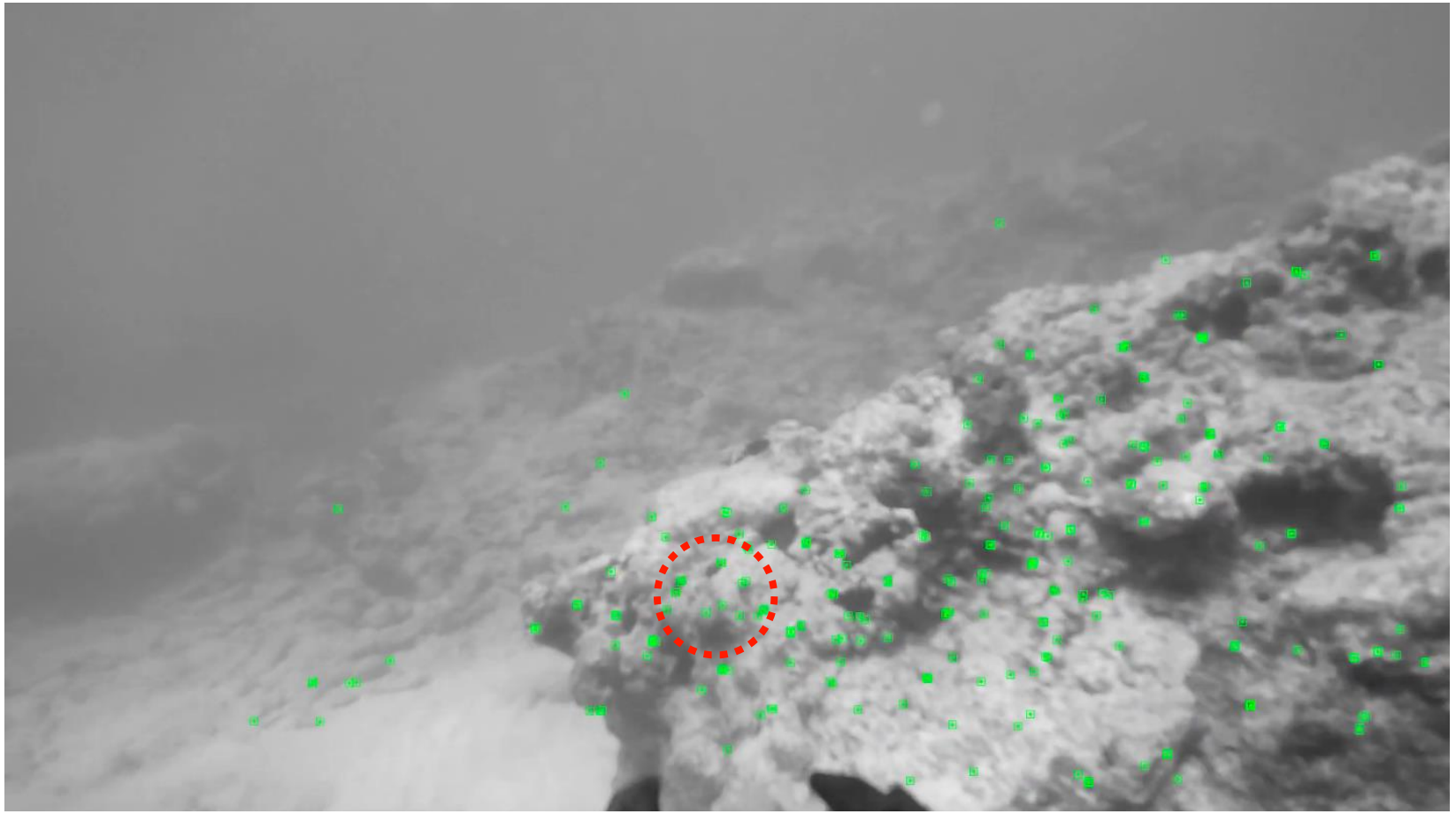


ORB-SLAM Implementation

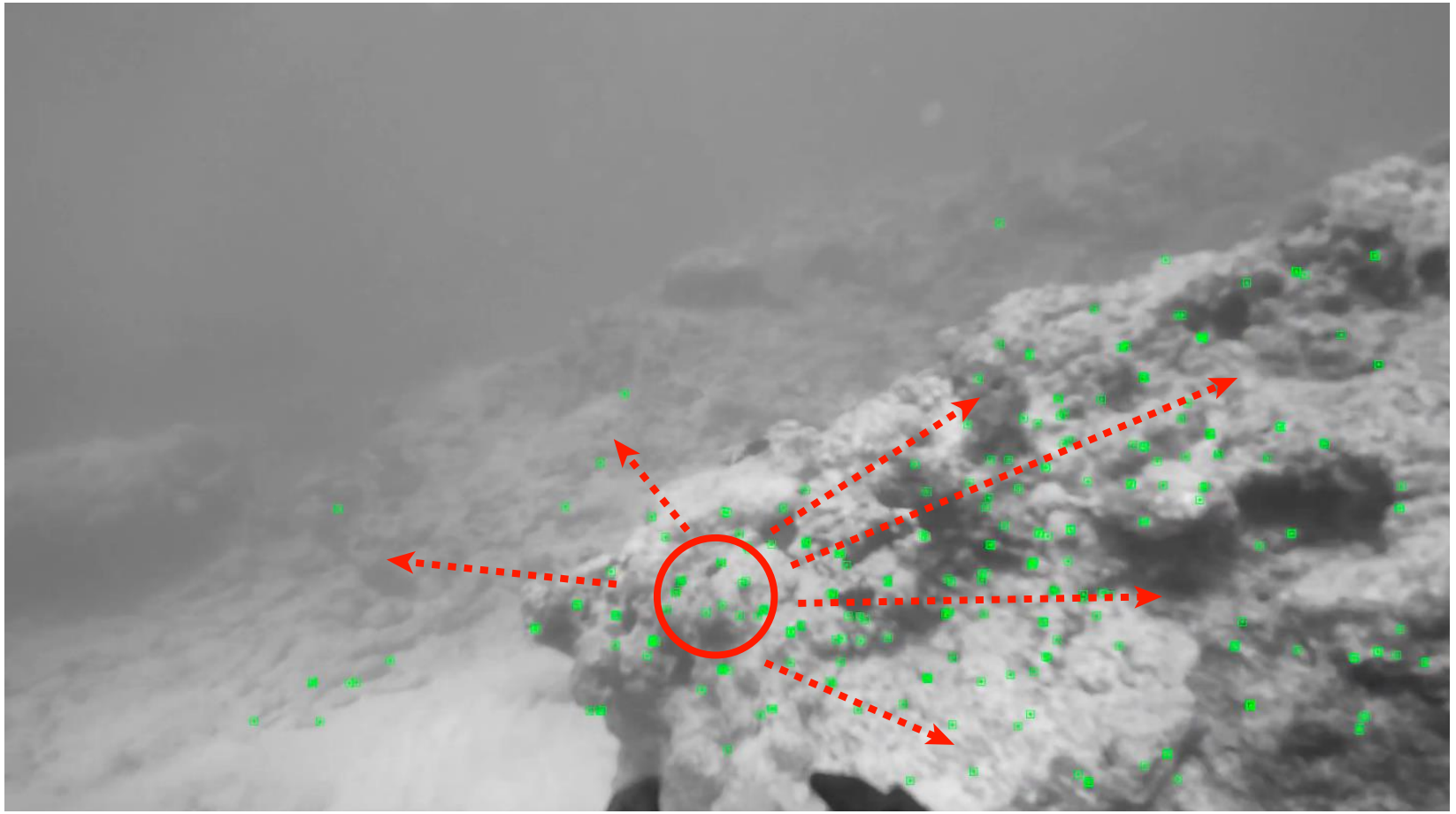
Raw

Corrected

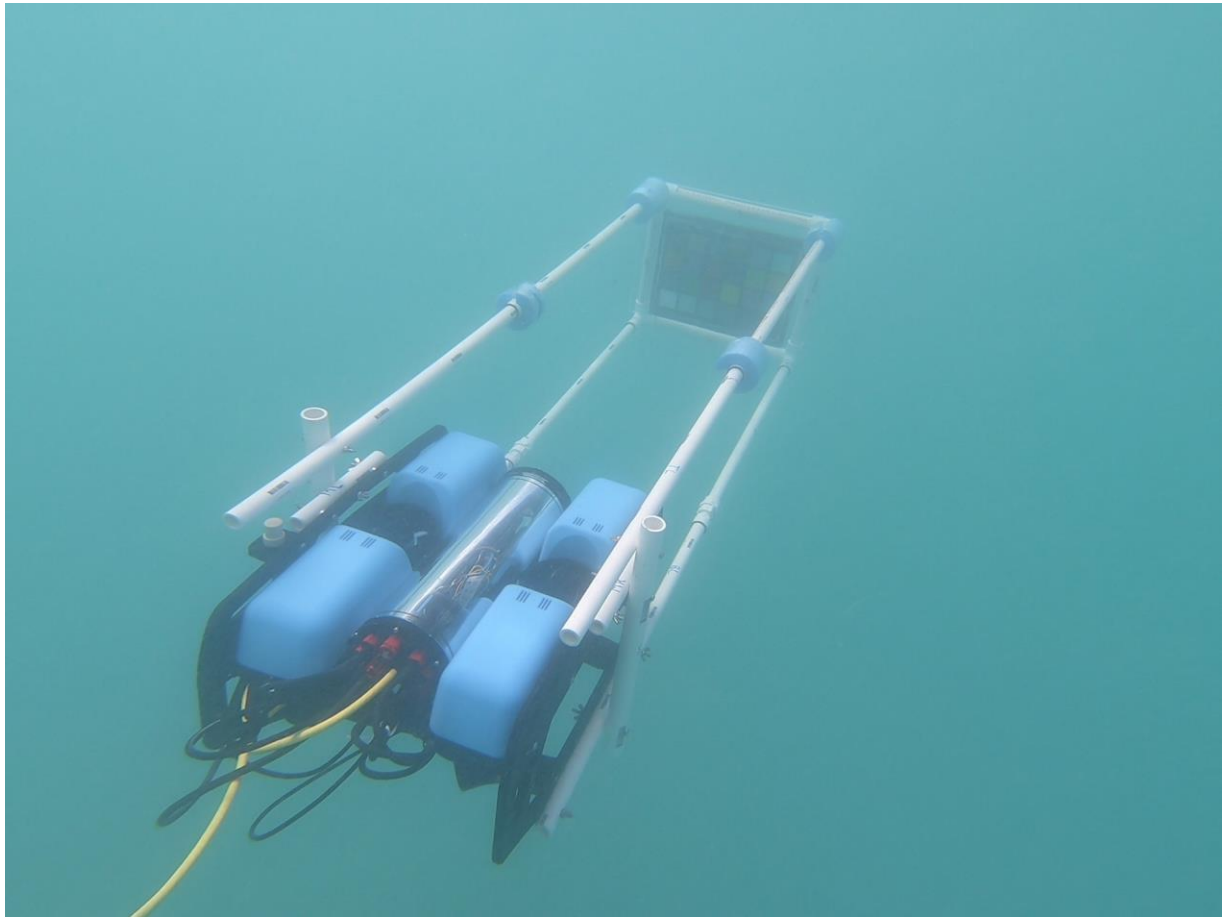
Integration of Echo Sounder



Propagate Depth Adjustments



Initialization and Calibration



- Color Chart for collecting attenuation values
- 3D structure with known irregularities to match echo sounder readings to tracked ORB-SLAM features

Future Work

- Integrate the echo sounder readings into the experiments
- Quantify the improvement in monocular SLAM and image color correction
- Extend experiments to account for different underwater environments
- Apply method to the BlueROV2 and a surface vehicle