DEEP-UNDER ROV (Year 2)

Development of **E**xperimental and **E**xploratory **P**hotogrammetry
for Supporting **U**nderwater Archaeological Studies using **R**emotely **O**perated **V**ehicle

Riset Dosen Muda ITB 2026

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Abstract

Indonesia hosts hundreds of submerged archaeological sites, yet their documentation remains limited by safety risks, high survey costs and the challenges of underwater sensing. In its second year, the **DEEP-UNDER ROV** project matured a low-cost Remotely Operated Vehicle, the **SUPRI-ROV** (Submersible Underwater Platform for Research and Inspection), from a 4-DOF prototype into a 6-DOF survey platform and built a perception-driven control and mapping stack around it: a Gazebo/ROS 2 simulator, stereo-enhanced image-based visual servoing (IBVS), visual-inertial state estimation, and a PINAX refraction-aware stereo visual-inertial SLAM. Tests at Saraga Pool and Pramuka Island produced 3D reconstructions using visual SLAM, photogrammetry and Gaussian Splatting.

Keywords: remotely operated vehicle, visual servoing, visual-inertial SLAM, underwater photogrammetry, underwater archaeology.

Introduction

Rationale

- KKP has identified 463 shipwreck locations across 21 Indonesian maritime regions, e.g. Riau Islands, Karimata Strait, Bangka Belitung and the Java Sea.
- Diver-based surveys are risky and survey-grade instruments (USBL, MBES) are costly, so most sites remain undocumented.
- Refraction and turbidity in shallow tropical waters degrade feature tracking and 3D reconstruction.

Objectives

- Develop a low-cost ROV for Indonesian shallow-water environments.
- Design visual survey-grade control and navigation for the ROV.
- Test multiple mapping techniques (photogrammetry, SLAM) in controlled and relevant environments.
- Build 3D models of underwater archaeological objects.

Novelties

- **Stereo-enhanced IBVS** for real-time ROV stabilisation during image acquisition in turbid, shallow waters.
- **Visual-inertial state estimation** fusing stereo features and IMU data to estimate ROV velocity without costly underwater positioning systems.
- **PINAX camera-model rectification** embedded in a stereo visual-inertial SLAM pipeline to compensate underwater refraction.

Outputs

- H. Tnunay et al., "Stereo-Enhanced Image-Based Visual Servoing for Low-Cost Underwater ROV," **IEEE ASCC 2026**, Bali (published).
- PINAX visual-inertial stereo SLAM, submitted to **ROSE Workshop, IROS 2026**.
- Q1 journal manuscript on VI-SLAM and stereo IBVS (in preparation).
- SUPRI-ROV v3.0 platform, Gazebo/ROS 2 simulator and underwater datasets.

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Research Method



Figure 1. SUPRI-ROV iterations: v1.0 (Sep 2025, 4-DOF), v2.0 (Jan 2026, 4-DOF) and v3.0 (May 2026, 6-DOF).

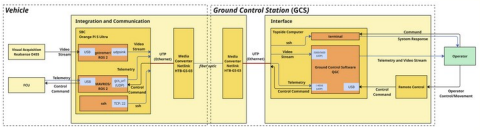


Figure 2. Architecture of the SUPRI-ROV system: vehicle (left) and ground control station (right).

Discussion & Result

1. SUPRI-ROV v3.0 Platform – 6-DOF vehicle with improved sealing, internal cable management, penetrator power switch, leak sensors, fibre-optic tether and ground-control integration, built mostly from domestically sourced components.

2. SUPRI-ROV Simulator – A Gazebo/ROS 2 model of the vehicle is used to test controllers before real-system deployment.

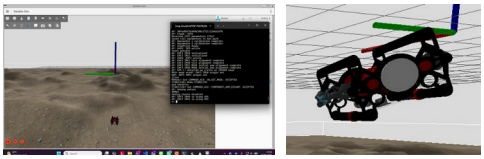


Figure 3. SUPRI-ROV simulator in Gazebo/ROS 2.

3. Stereo-enhanced IBVS – Underwater image correction, AprilTag corner detection and stereo triangulation feed an image-based visual servoing controller that stabilises the ROV during image acquisition.

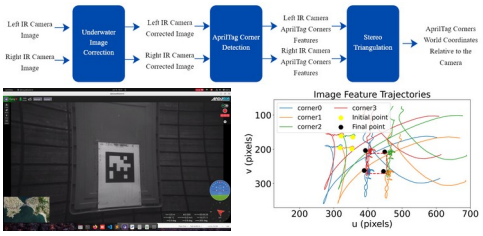


Figure 4. IBVS data flow (top); rectified underwater image and feature trajectories converging to the target (bottom).

Conclusion

- A low-cost 6-DOF ROV with stereo IBVS, visual-inertial state estimation and refraction-aware SLAM has been developed and validated in pool and coastal tests.
- Pramuka Island field mission (21–25 Oct 2026): SUPRI-ROV was tested in open water and mapped the Pramuka shipwreck and surrounding coral reef.
- Next: Q1 journal publication, dense 3D models of the shipwreck, and a multi-vehicle digital-twin survey platform.

4. Visual-inertial State Estimation – A Kalman-based estimator fuses stereo image features and IMU data to estimate the ROV body velocity required by IBVS; the estimate settles when the ROV is held steady.

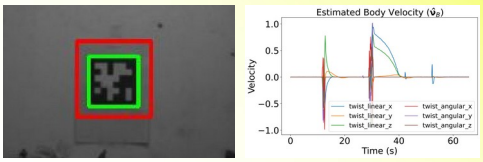


Figure 5. Tracked stereo features (left) and estimated body velocity (right).

5. PINAX Visual-inertial Stereo SLAM – The PINAX camera model rectifies refraction-distorted stereo images before tracking and mapping, giving a consistent trajectory and sparse point cloud of an underwater frame.



Figure 6. VI-SLAM pipeline, PINAX trajectory and sparse point cloud (Saraga Pool).

6. Underwater 3D Reconstruction – SUPRI v3.0 captured an ADCP support frame at Pramuka Island and a rigid frame at Saraga Pool, reconstructed with visual SLAM, photogrammetry and Gaussian Splatting.



Figure 7. ADCP frame 3D model and Gaussian Splatting (Pramuka), D455 stereo reconstruction (Saraga).

7. Field Mission at Pramuka Island (21–25 Oct 2026) – SUPRI-ROV was deployed in open water over coral reef and calibration targets, and mapped the Pramuka shipwreck.

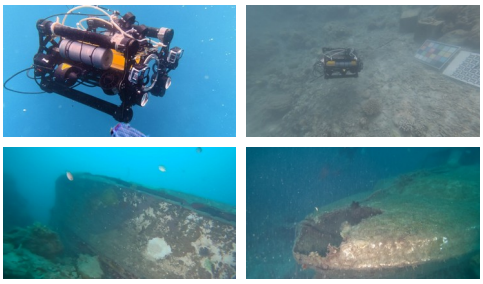


Figure 8. SUPRI-ROV in open water and over the coral reef with calibration targets (top); Pramuka shipwreck captured by SUPRI-ROV (bottom).

Project Website

Scan for SUPRI-ROV design, videos, 3D reconstructions, team, datasets and publications.

deep-under-rov.github.io