Comparison of Monocular and Stereo Vision approaches for Structure Inspection using Autonomous Underwater Vehicles

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1 - Abstract

In the context of **autonomous underwater structure inspection**, this work proposes a **comparison** between **monocular** and **stereo vision** approaches for estimating the lateral velocity of an Autonomous Underwater Vehicle (**AUV**) and its orientation with respect to a target surface.

Keywords: autonomous underwater vehicles, AUVs, visual odometry, underwater inspections, vision-based navigation

2 - Problem statement & contributions

PROBLEM:

- Periodical inspections as fundamental operations to monitor the status of water-based infrastructures.
- Inspection missions generally executed by specialised divers [1], resulting in **dangerous** and **expensive tasks**.
- **AUVs** as an **alternative solution** to divers to perform underwater structure inspections.

GOAL:

Evaluation of **monocular** and **stereo vision** approaches for the realisation of a **vision-based strategy** allowing an **AUV** to **autonomously inspect** underwater structures.

CONTRIBUTIONS:

1. **Experimental validation** of the vision-based building blocks of the strategy proposed in [2] for hull inspection.
2. **Evaluation** of the **monocular Visual Odometry** (VO) proposed in [3] integrated within the framework of [2].
3. **Comparison** of **monocular** and **stereo vision** exploited during an inspection task to estimate:
   - **lateral velocity** of the underwater robot;
   - **relative orientation** between the AUV and the target.

3 - Methodology

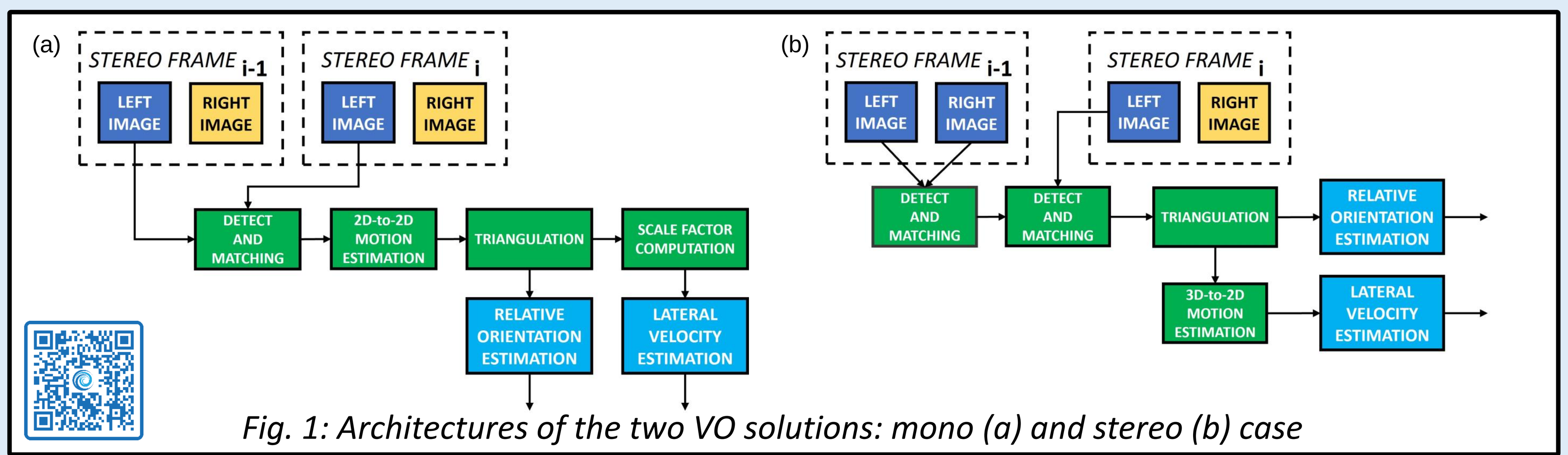

Fig. 1: Architectures of the two VO solutions: mono (a) and stereo (b) case

Robot **lateral velocity** estimated exploiting **two strategies** of **VO**:

- monocular VO using frontal range information to solve scale ambiguity;
- stereo VO based on a 3D-to-2D feature correspondence approach.

Relative orientation retrieved by using **3D pointcloud** from triangulation of 2D features:

- between consecutive images in the monocular case;
- between stereo frames in the stereo vision approach.

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[2] Interuniversity Center of Integrated Systems for the Marine Environment (ISME)
[3] Centro di Ricerca "E. Piaggio"

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4 - Equipment setup & working scenario

Exteroceptive payload:

- Frontal stereo vision system
- Frontal acoustic range sensor

Navigation sensors:

- Attitude and Heading Reference System (AHRS)
- Doppler Velocity Log (DVL)
- Depth sensor
- GPS

Fig. 2: Zeno AUV – Reference underwater vehicle utilised during the tests

Fig. 3: Aerial view of the operational scenario

Zeno AUV remotely **driven** to acquire underwater images of a pier.

Execution of **two** different experimental **tests**:

- robot in hovering configuration;
- robot moving at constant lateral velocity.

5 - Experimental results

Relative orientation estimation

- Vision-based estimates compared with **ground truth** (GT) computed using **AHRS readings** and pier **geographical information**.
- **Stereo** approach **more effective** than monocular one due to the reduced inter-frame baseline in hovering configuration.

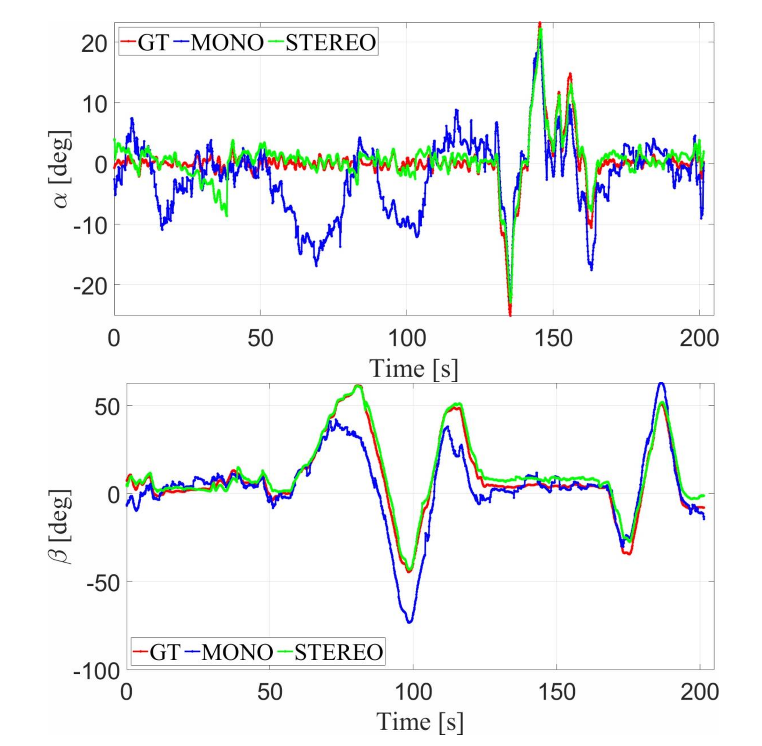

Fig. 4: Trend of the relative orientation estimates

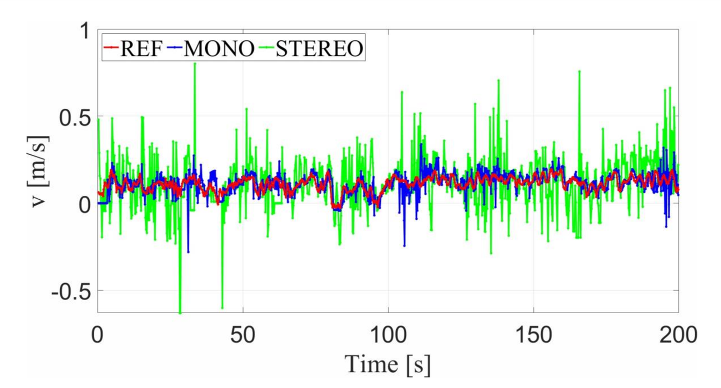

Fig. 5: Trend of the lateral velocity estimates

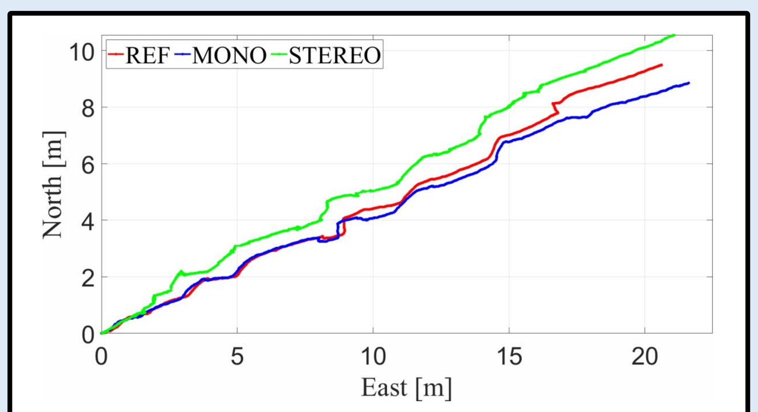

Fig. 6: Trajectory executed by the AUV

Lateral velocity estimation

- VO estimates compared with **reference signal** (REF), corresponding to **sway** linear velocity measured by the **DVL**.
- **Monocular** VO solution performs **better** than the stereo one, which tends to be particularly noisy.
- AUV **trajectories** obtained from VO estimates are **consistent** with the DVL-based reference path (REF).

6 - Conclusion & future works

Stereo and monocular vision approaches provide relative orientation and lateral velocity **consistent** with the corresponding references:

→ stereo: reliable relative orientation also if robot is hovering;

→ monocular: lower lateral velocity estimation errors.

- Modify the inspection framework to **jointly exploit** monocular and stereo vision approaches.
- **Integrate** the strategy **onboard** Zeno AUV for **real-time testing**.

References:

[1] D. Hogan, "Out of sight, out of mind; the importance of underwater inspections," J.F. Brennan Company, Inc. Retrieved April 7, 2023, from https://www.jfbrennan.com/blog/out-of-sight-out-of-mind.

[2] S. Tani, F. Ruscio, M. Bresciani, A. Caiti, and R. Costanzi, "Stereo Vision System for Autonomous Ship Hull Inspection," IFAC-PapersOnLine, 55(31), 375-380, (2022).

[3] F. Ruscio, S. Tani, M. Bresciani, A. Caiti, and R. Costanzi, "Visual-based Navigation Strategy for Autonomous Underwater Vehicles in Monitoring Scenarios," IFAC-PapersOnLine, 55(31), 369-374, (2022).