A low-cost, open-source framework for tracking animals in aquatic ecosystems

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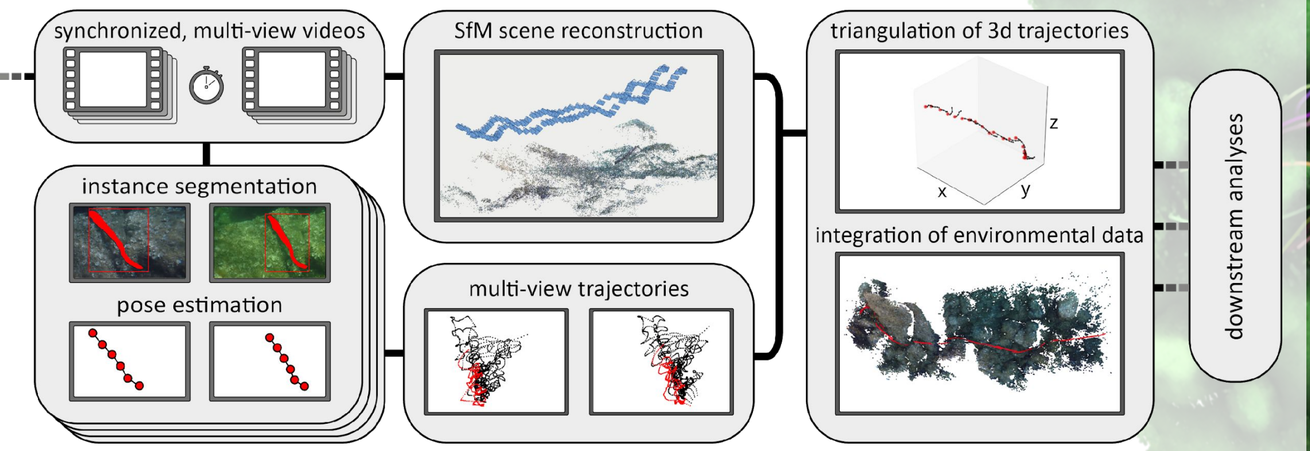
Abstract

Common methods for tracking animals under water exist, but frequently involve costly infrastructure or the manipulation of the animals [1, 2].

We present a framework solely relying on low-cost cameras, combining structure-from-motion (SfM) and deep-learning for object detection.

Implementing our method allows highly accurate tracking of animal positions and body postures in various scenarios, for example single individuals in a complex environment or schools of fish.



Background

Markerless animal tracking for behavioral analyses has become commonly available, however, these techniques often lack the robustness for deployment in natural scenarios [4].

Recording animal behavior in aquatic environments has further limitations (e.g. GPS does not penetrate water, expensive equipment required) [1, 2].

As an alternative, we provide a semi-automated workflow, that guides the user through the required steps using computer vision and object detection methods.

Methods

(1) Transfer-learning an instance segmentation model (Mask R-CNN) with custom datasets [4]

(2) SfM reconstructions of the visual scene using COLMAP [5]

(3) Generating trajectories from Mask R-CNN predictions with optional, contour-based animal postures

(4) Triangulation of 3D trajectories

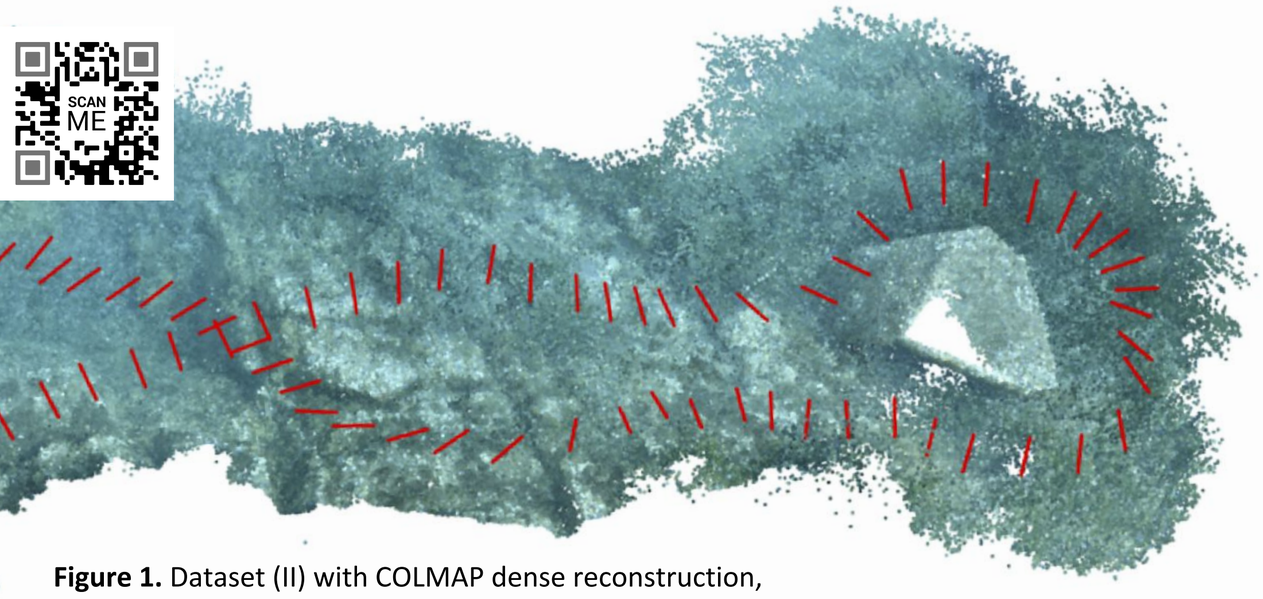


Figure 1. Dataset (II) with COLMAP dense reconstruction, calibration wand visualized at 0.5 Hz.

[1] Krause, Jens, et al. "Reality mining of animal social systems." *Trends in ecology & evolution* 28.9 (2013): 541-551.

[2] Jepsen, Niels, et al. "Surgical implantation of telemetry transmitters in fish: how much have we learned?." *Aquatic Telemetry*. Springer, Dordrecht, 2002. 239-248.

[3] Graving, Jacob M., et al. "Fast and robust animal pose estimation." *bioRxiv* (2019): 620245.

[4] He, Kaiming, et al. "Mask r-cnn." *Proceedings of the IEEE international conference on computer vision*. 2017.

[5] Schonberger, Johannes L., and Jan-Michael Frahm. "Structure-from-motion revisited." *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*. 2016.

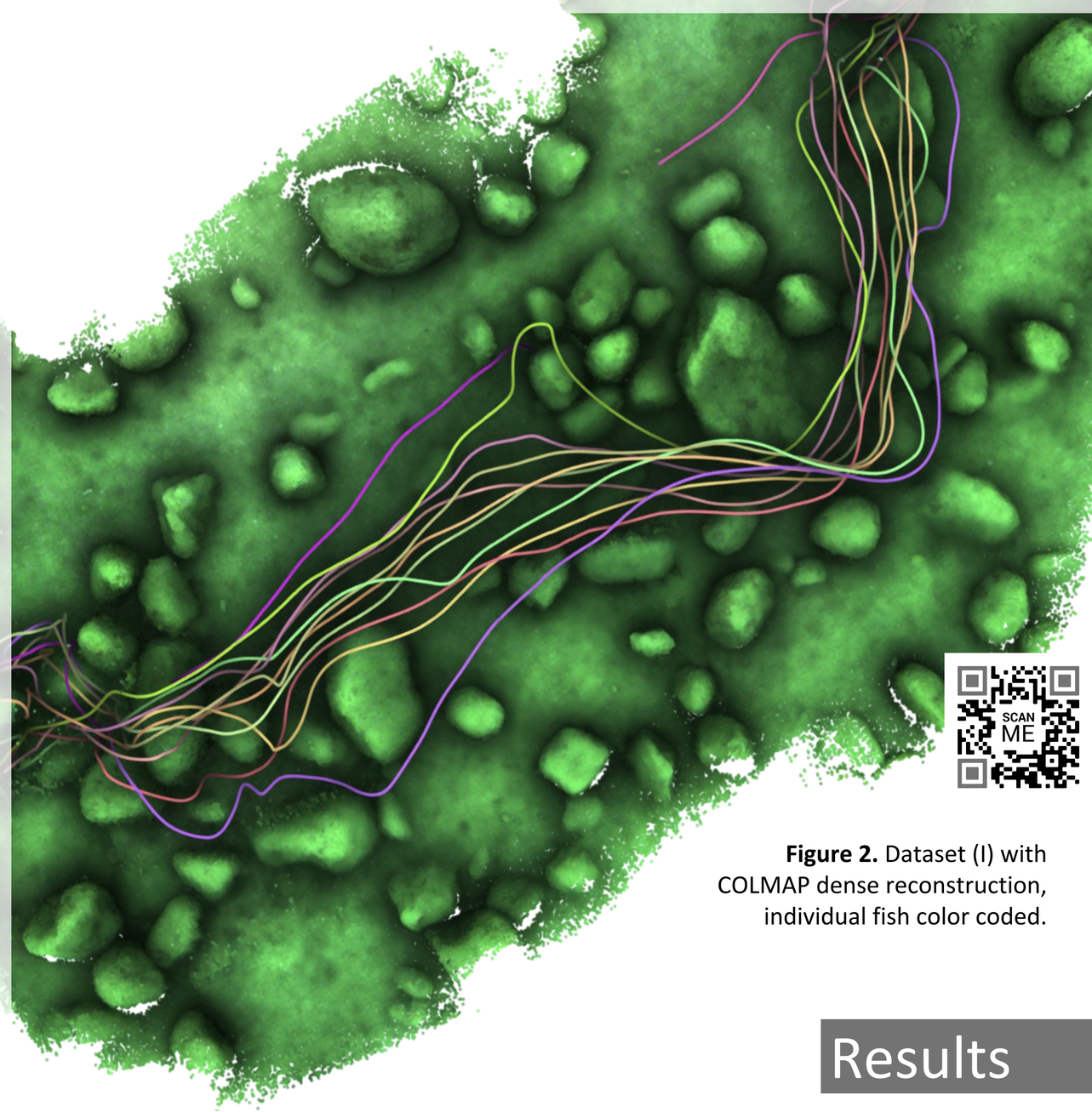


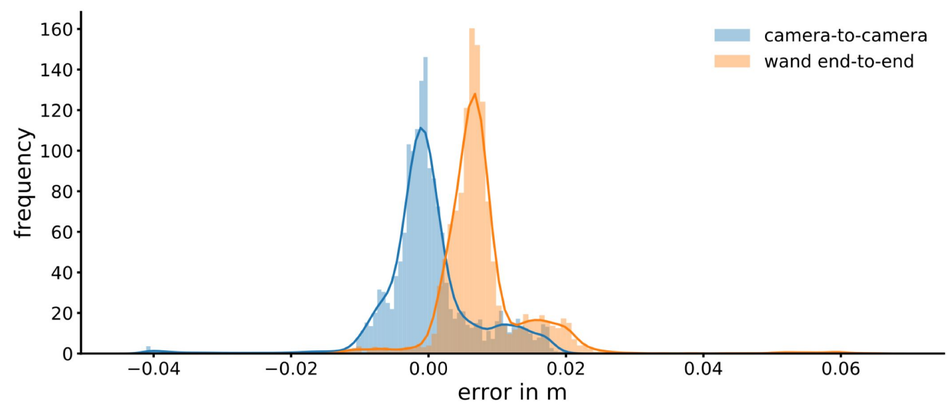
Figure 2. Dataset (I) with COLMAP dense reconstruction, individual fish color coded.

Results

Here, we showcase our method with two example datasets:

(I) Fish school (*Lamprologus c.*, > 10 individuals), recorded with 12 GoPro Hero 4 cameras, Lake Tanganyika (see Fig. 2)

(II) Calibration wand (0.5 m) in a complex environment, recorded with four GoPro Hero7 cameras, Corsica (see Fig 1.)



Dataset (II) allowed ground-truth inference, resulting in marginal tracking errors considering the scale of the reconstruction (25 x 10 m):

- Calibration wand end-to-end distance: 0.011 m RMSE
- Camera-to-camera distance: 0.007 m RMSE

Discussion

- Our framework allows non-invasive, yet detailed tracking of aquatic organisms in their natural habitat.
- High-resolution trajectories enable the application of behavioral analyses that so far required standardized laboratory environments.
- Environmental conditions (e.g. underwater lighting, high turbidity) that impede tracking can be compensated with additional animal tagging.
- Our method is cheap in application and deployable with minimal investment due to consumer grade cameras and open-source software.

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