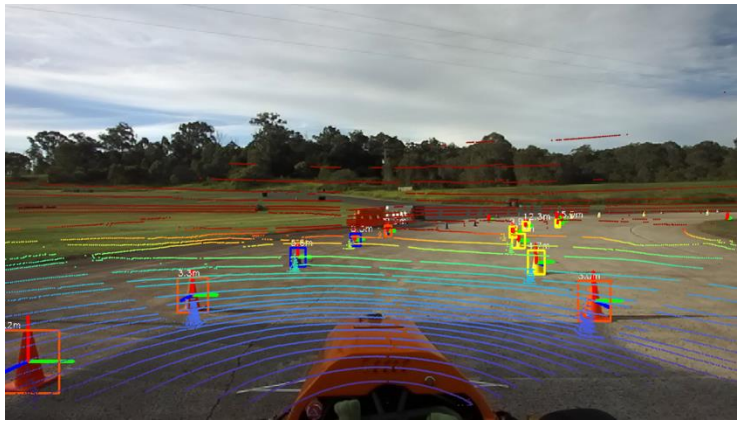
Localisation and Mapping for QUT Motorsport

Student: Beverley Gorry, n10215131

Supervisors: Dr Tobias Fischer, Dr Alejandro Fontan

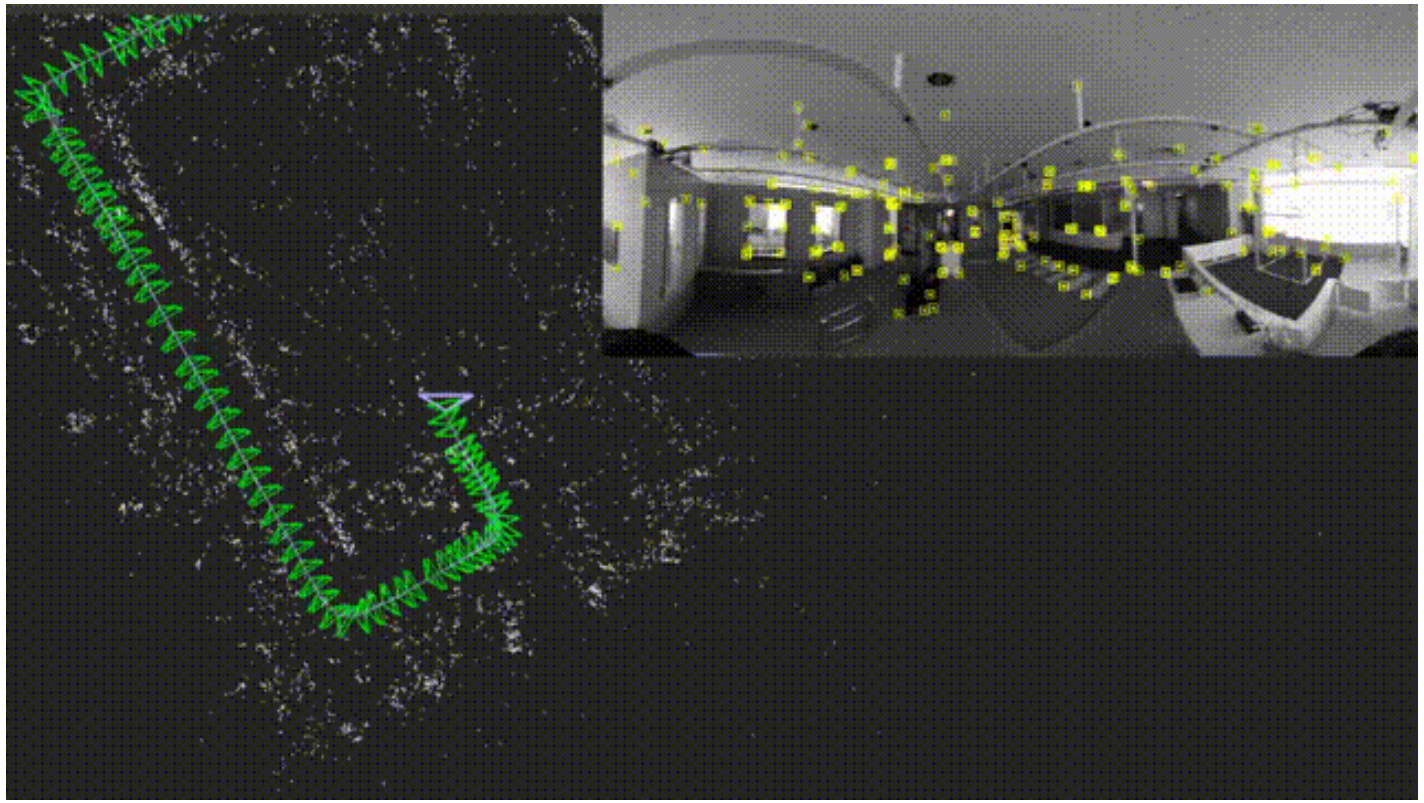
QUT Motorsport

What can we learn from how a human driver balances high speed and safety to optimise performance?



Background Context

VSLAM: *Visual Simultaneous Localisation and Mapping*



OpenVSLAM [1]

[1] S. Sumikura, M. Shibuya, K. Sakurada, "OpenVSLAM: A Versatile Visual SLAM Framework," in Proceedings of the 27th ACM International Conference on Multimedia, 2019.

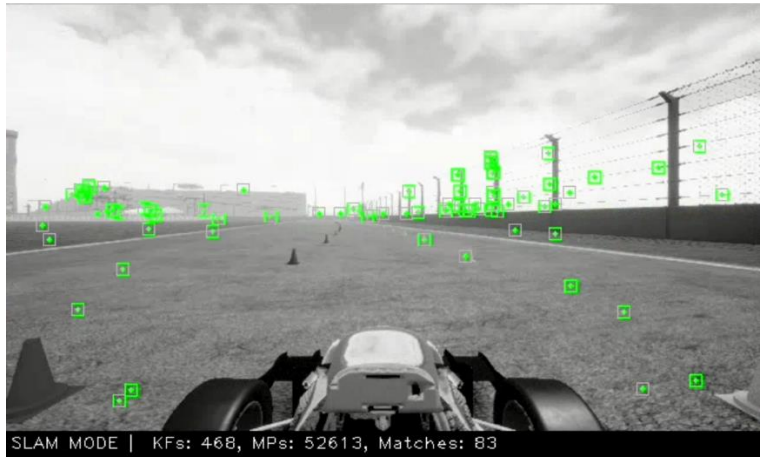
Aims & Objectives

Challenges

- **Landmark detection** in a sparse scene
- **Loop closure** with a lack of texture and repetitive features

Objectives

- **Evaluate** state-of-the-art SLAM systems
- **Modify** a system for a racetrack scene
- **Test** loop closure and relocalisation



ORB SLAM 2[1] on a suburban sequence (left) and racetrack sequence (right).

[1] R. Mur-Artal, J. Tardos. "ORB-SLAM2: An Open-Source SLAM System for Monocular, Stereo, and RGB-D Cameras," in IEEE Transactions on Robotics, vol. 33, no. 5, pp. 1255–1262, 2017.

Research Questions

How do existing state-of-the-art SLAM methods perform **comparatively**?

How can existing methods be modified to **improve** the QUT Motorsport driverless perception pipeline?

How can the **viability** of a **SLAM** method be verified for high-speed applications using a racetrack scene?

Related Work

Feature-Based SLAM	⊕ Loop closure detection.[1]	⊖ Rely on landmark density.[2] ⊖ Feature loss in fast environments.[3]
Direct Methods	⊕ Visual odometry in environments with little texture.[4]	⊖ Cannot achieve loop closure.[5] ⊖ Rely on high-quality and slow-moving video frames.[5]

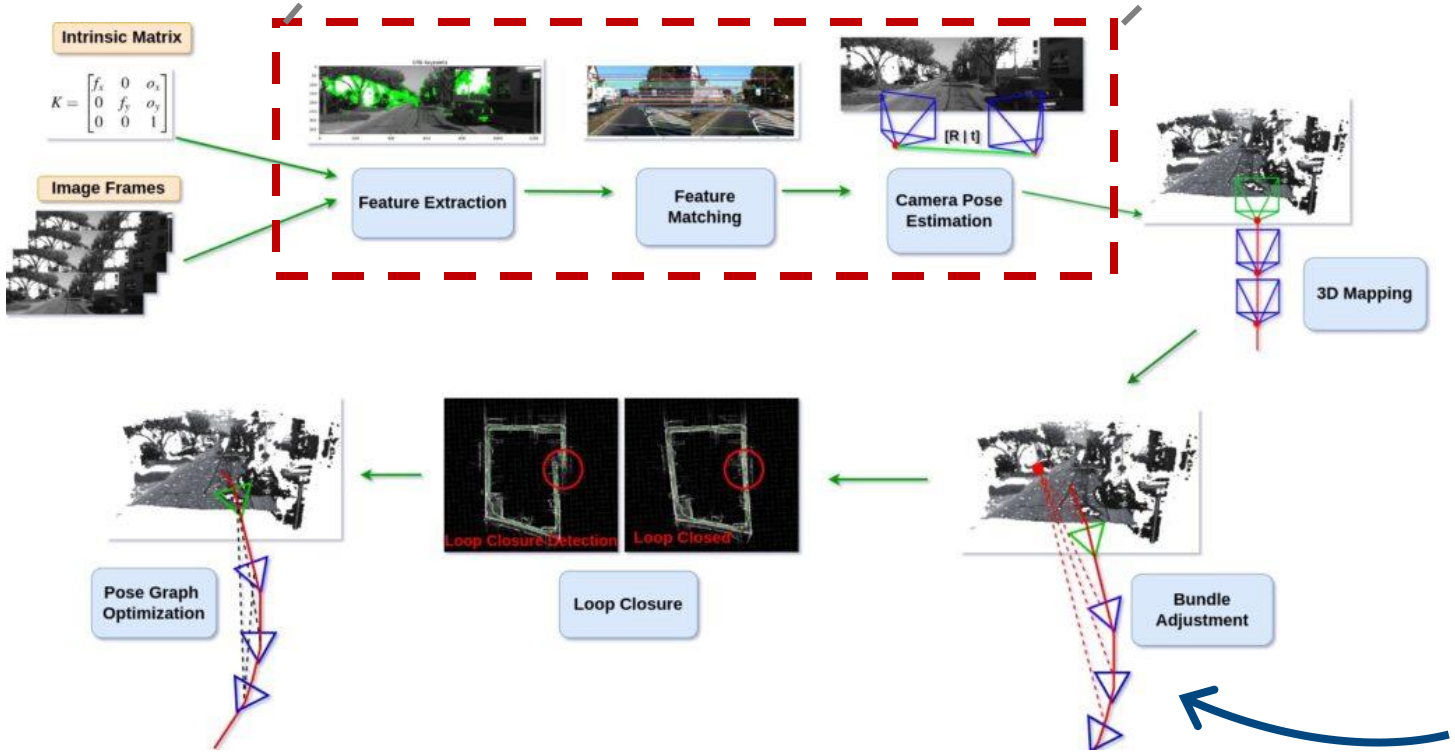
DIRECT

FEATURE-BASED

[1] S. Li, T. Zhang, X. Gao, D. Wang, and Y. Xian, "Semi-direct monocular visual and visual- inertial SLAM with loop closure detection," Robot. Auton. Syst., vol. 112, pp. 201–210, Feb. 2019, doi: 10.1016/j.robot.2018.11.009.
[2] C. Cadena et al., "Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust Perception Age," IEEE Trans. Robot., vol. 32, no. 6, pp. 1309–1332, Dec. 2016, doi: 10.1109/TRO.2016.2624754.
[3] X. Dong, L. Cheng, H. Peng, and T. Li, "FSD-SLAM: a fast semi-direct SLAM algorithm," Complex Intell. Syst., vol. 8, no. 3, pp. 1823–34, 2022, doi: 10.1007/s40747-021-00323-y.
[4] J. Engel, V. Koltun, and D. Cremers, "Direct Sparse Odometry," IEEE Trans. Pattern Anal. Mach. Intell., vol. 40, no. 3, pp. 611–625, Mar. 2018, doi: 10.1109/TPAMI.2017.2658577.
[5] A. Tourani, H. Bavle, J.L.Sanchez-Lopez, and H.Voos, "Visual SLAM: What Are the Current Trends and What to Expect?," Sensors, vol. 22, no. 23, p. 9297, Nov. 2022, doi: 10.3390/s22239297.

Methodology

Assumes a **static environment**



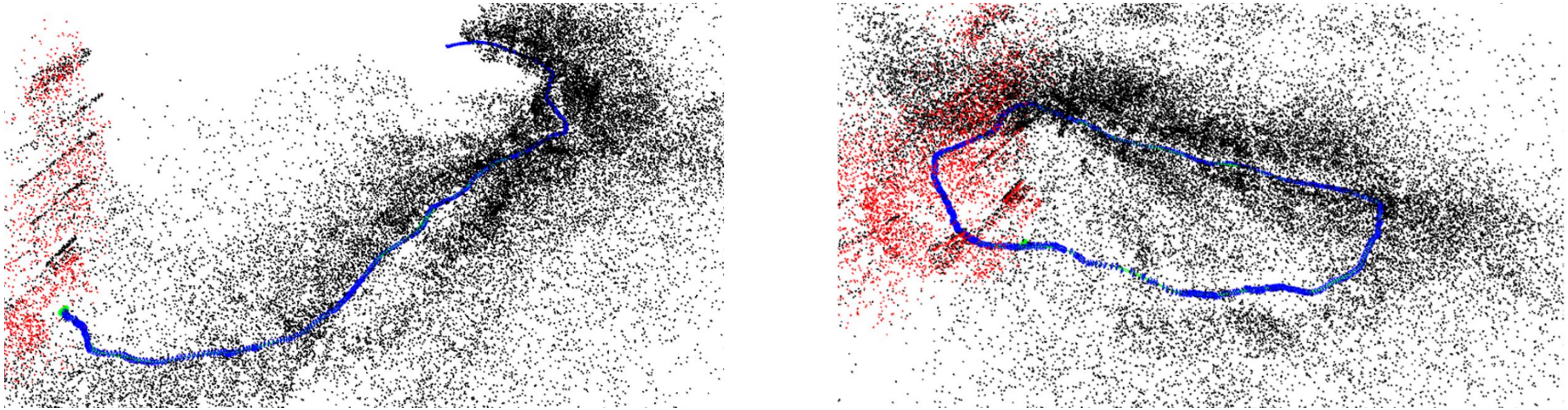
Source: Learn OpenCV [1]

Filtering keypoints

Frequent keyframe insertion

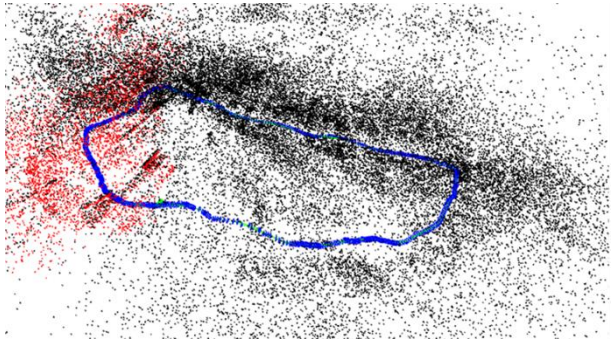
[1] "Understanding Monocular SLAM implementation in Python OpenCV," LearnOpenCV – Learn OpenCV, PyTorch, Keras, Tensorflow with code, & tutorials, Jun. 18, 2024. https://learnopencv.com/monocular-slam-in-python/ (accessed Oct. 02, 2024).

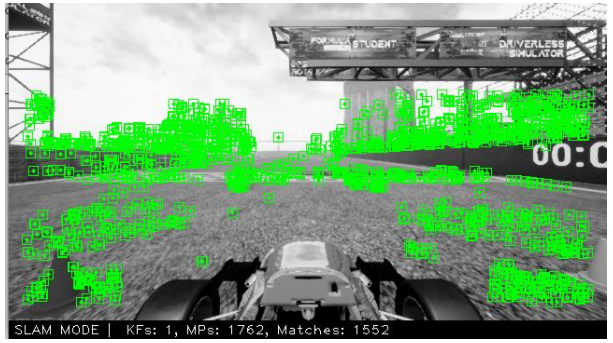
Loop Closure

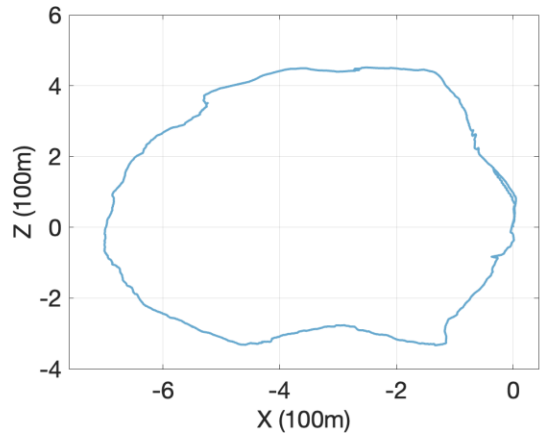


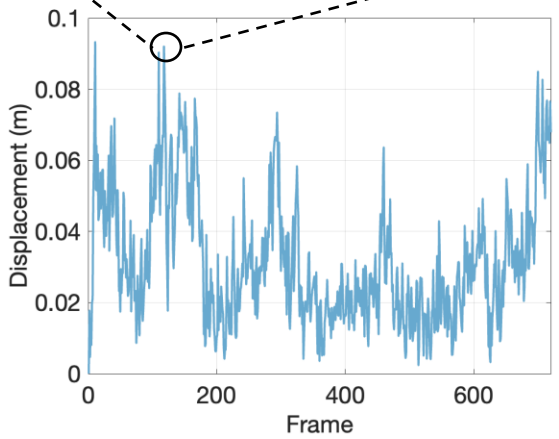
The trajectory before (left) and after (right) performing loop closure.

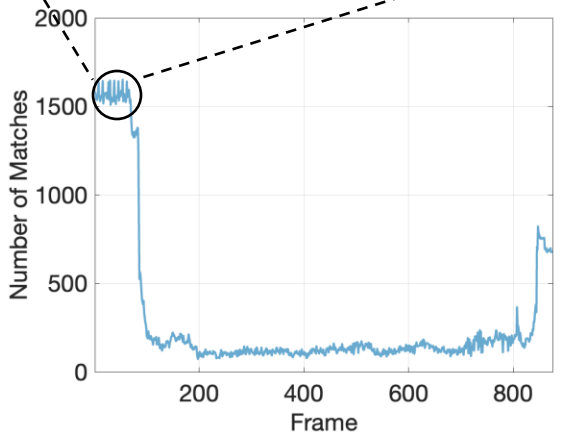
Evaluation







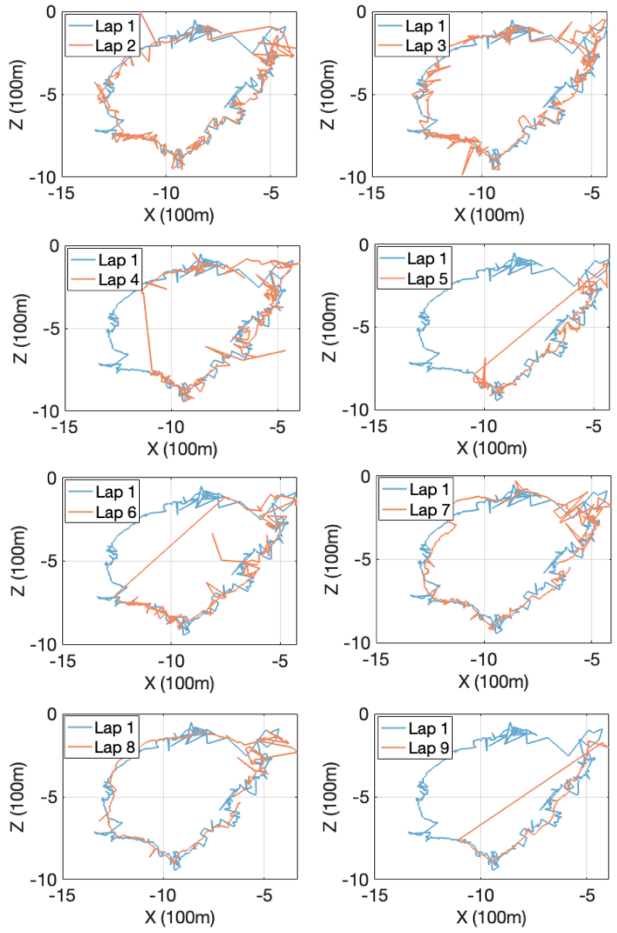


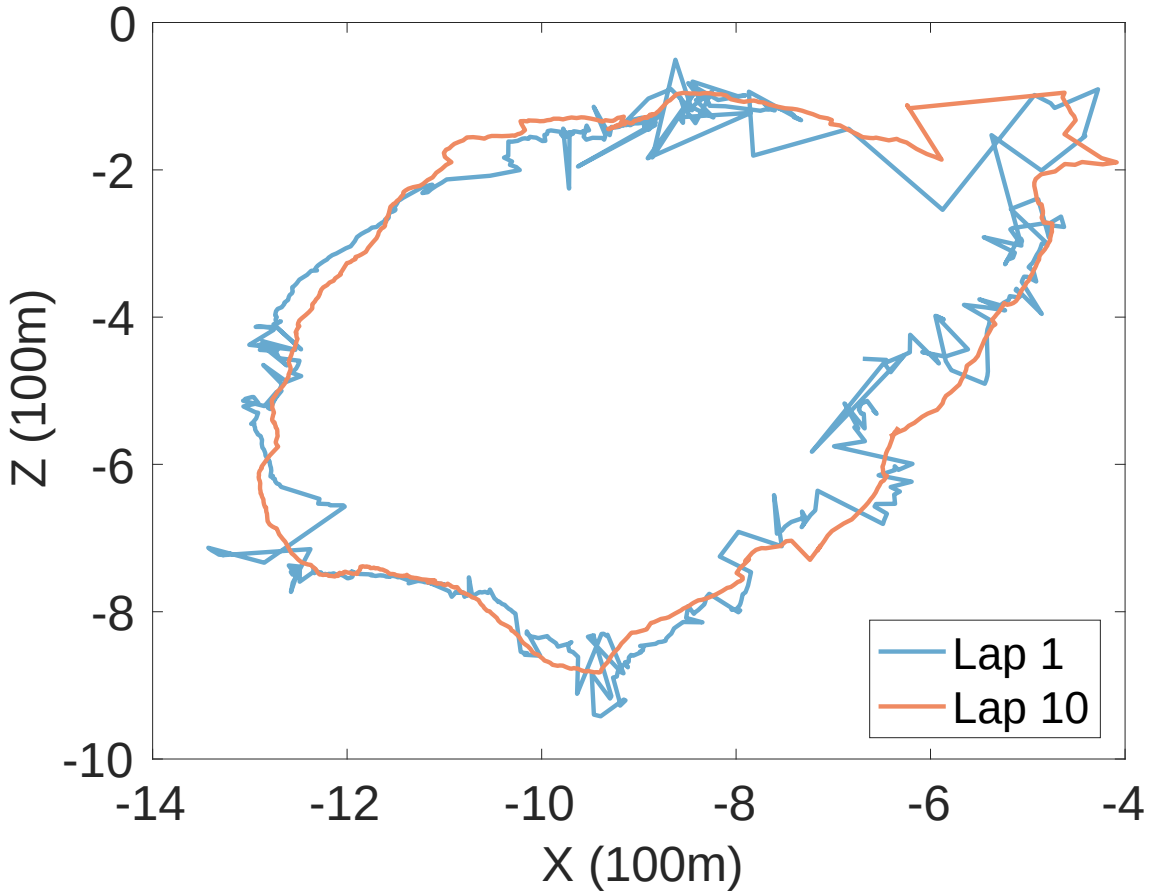


ORB SLAM2 map viewer (top left), frame 118 corresponding to the highest peak in displacement per frame (top middle), starting frame corresponding to stationary matches (top right), key frame trajectory (bottom left), displacement per frame (bottom middle), number of matches per frame (bottom right).

Evaluation

Lap 1 vs:	ATE (m)
2	0.465
3	0.478
4	0.535
5	0.508
6	0.504
7	0.531
8	0.436
9	0.462
10	0.416



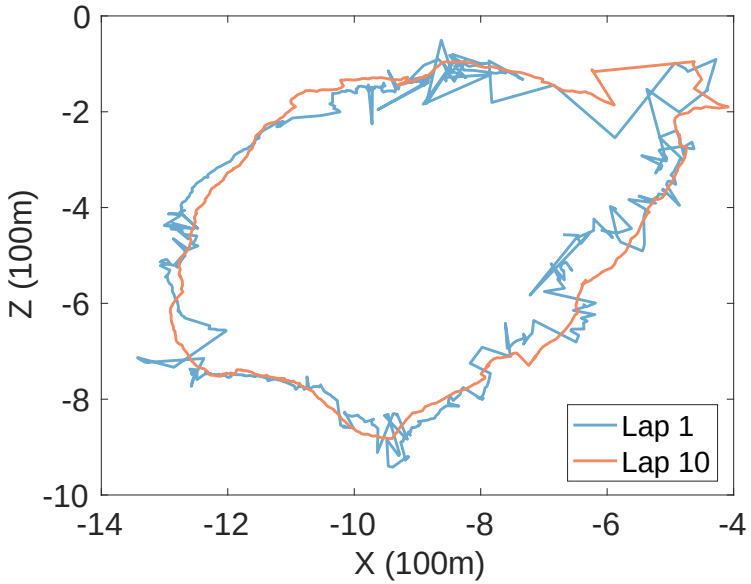


Keyframe trajectory of lap 1 compared against laps 2-10.

Research Significance & Future Work

Contributions

- Modified feature-based SLAM system for a racetrack environment
- Verified viability of SLAM for high-speed challenging environments using motorsport
  - Map reuse, loop closure, **relocalisation**



Future Work

- Integrated SLAM methods
- Ground truth reference
- Constrain system using the vehicle's dynamics

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