

Chapter 1

Abstract

The goal of this project is to implement and test a full-stack racing strategy for single vehicle and head-to-head racing, with a focus on integrating and testing pipeline components. The goal is to create benchmark tests to evaluate key characteristics each pipeline component. The tests will also evaluate the response to noisy data input to evaluate the robustness of each component. Lap time on different maps will be used as an over all measure of performance for each component.

The chapters are as follows:

1.1 Chapter 1

An overview of the theory. This includes all pipeline components as well as current techniques/methods and algorithms used in the pipeline

1.2 Chapter 2

Literature review

1.3 Chapter 3

Testing for perception

The following characteristics are to be evaluated:

- accuracy - mean error and max error (laptime/percentage completion can also be used as a proxy measurement)
- maximum number of particles
- computational power
- sample frequency from sensors

1.4 Chapter 4

Testing for planning

The overtaking ability of the car needs to be evaluated to test the local planner.

The safety of the race line (distance from walls) and lap time must be balanced for the global planner

1.5 Chapter 5

Testing for control

The following characteristics are to be evaluated:

- Tracking accuracy - percentage of planned line followed, mean error and max error
- max/min control frequency
- computational power
- lookahead distance

1.6 Chapter 6

Testing for head to head racing

Opponent detection and tracking will be tested (more research must be done to find out how)

1.7 Chapter 7

Real world testing

A test track will have to be created with cameras to accurately track the cars pose and other characteristics.

1.8 Chapter 8

Discussion of results

1.9 Chapter 9

Conclusion

Chapter 2

Lit Review

2.1 Perception

2.1.1 Problems

2.2 Planning

2.2.1 Problems

2.3 Control

2.3.1 Problems

Chapter 3

Rough

[1]
[2]
[3]
[4]
[5]

3.1 Pipeline

3.1.1 Perception

The goal of the perception pipeline is to efficiently provide accurate cone position and color estimates as well as their uncertainties in realtime.[5]

Perception is the general term for all algorithms that perceive the environment and derive knowledge about it. It includes detecting objects, detecting free space, mapping the environment and localizing the autonomous vehicle. [6] defines the fundemental problems of perception as:

- High speed object detection
- High speed localization and state estimation
- Localization on wide areas without specific landmarks
- Precise localization information necessary to achieve high dynamic trajectory planning and control

Perception algorithms include localization and object detection [6]

Common Localistaion methods:

To do look at all algorithms (1)

simultaneous localization and mapping

Adaptive Monte Carlo Localization

LiDAR distortion compensation

extended H_∞ filter

Particle filter ?

[6]

3.1.2 Planning

Planning involves the algorithms that plan the trajectories for vehicle to drive around the track.[6]

Global Planning Global planning provides an optimal path, better known as raceline, around the racetrack. In the context of racing, global planning often optimizes for the lowest lap time. Therefore, when following this raceline, the car drives an optimal path around the racetrack (under the constraints of the raceline generation) as fast as possible. [6]

Local Planning Local planning (or motion planning) plans on a finer granularity compared to global planning, usually under the assumption that an optimal global trajectory is provided. Local planners operate in a certain time horizon, and aim to avoid obstacles while still provide a fast and reliable path that does not deviate too much from the optimal global raceline. [6]

Behavioral Planning Behavioral planning provides information about the high-level mission planning of the racecar. This can include the decision making about overtaking maneuvers (overtaking left/overtaking right/stay behind), the energy management strategy, interaction with other vehicles and the reaction to inputs from race control (e.g., flags, speed limits). [6]

The fundamental goals of planning are as follows:[6]

- Minimum-time optimization for a global optimal raceline.
- Long local planning horizon for recursive feasibility.
- Obstacle avoidance and vehicle reaction at high speeds
- High re-planning frequency for real-time capability
- Decision making under high uncertainty
- Interaction planning with non-cooperative agents.

3.1.3 Control

To do...

- 1 (p. 5): look at all algorithms

Bibliography

- [1] Felix Nobis, Maximilian Geisslinger, Markus Weber, Johannes Betz, and Markus Lienkamp. A deep learning-based radar and camera sensor fusion architecture for object detection. In *2019 Sensor Data Fusion: Trends, Solutions, Applications (SDF)*, pages 1–7, 2019.
- [2] Johannes Betz, Alexander Wischnewski, Alexander Heilmeier, Felix Nobis, Tim Stahl, Leonhard Hermansdorfer, and Markus Lienkamp. A software architecture for an autonomous racecar. In *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring)*, pages 1–6, 2019.
- [3] Alexander Wischnewski, Maximilian Geisslinger, Johannes Betz, Tobias Betz, Felix Fent, Alexander Heilmeier, Leonhard Hermansdorfer, Thomas Herrmann, Sebastian Huch, Phillip Karle, Felix Nobis, Levent Ögretmen, Matthias Rowold, Florian Sauerbeck, Tim Stahl, Rainer Trauth, Markus Lienkamp, and Boris Lohmann. Indy autonomous challenge - autonomous race cars at the handling limits. In Peter Pfeffer, editor, *12th International Munich Chassis Symposium 2021*, pages 163–182, Berlin, Heidelberg, 2022. Springer Berlin Heidelberg.
- [4] Johannes Betz, Tobias Betz, Felix Fent, Maximilian Geisslinger, Alexander Heilmeier, Leonhard Hermansdorfer, Thomas Herrmann, Sebastian Huch, Phillip Karle, Markus Lienkamp, Boris Lohmann, Felix Nobis, Levent Ögretmen, Matthias Rowold, Florian Sauerbeck, Tim Stahl, Rainer Trauth, Frederik Werner, and Alexander Wischnewski. Tum autonomous motorsport: An autonomous racing software for the indy autonomous challenge. *Journal of Field Robotics*, 40(4):783–809, 2023.
- [5] Juraj Kabzan, Miguel I. Valls, Victor J. F. Reijgwart, Hubertus F. C. Hendriks, Claas Ehmke, Manish Prajapat, Andreas Bühler, Nikhil Gosala, Mehak Gupta, Ramya Sivanesan, Ankit Dhall, Eugenio Chisari, Napat Karnchanachari, Sonja Brits, Manuel Dangel, Inkyu Sa, Renaud Dubé, Abel Gawel, Mark Pfeiffer, Alexander Liniger, John Lygeros, and Roland Siegwart. Amz driverless: The full autonomous racing system. *Journal of Field Robotics*, 37(7):1267–1294, 2020.
- [6] Johannes Betz, Hongrui Zheng, Alexander Liniger, Ugo Rosolia, Phillip Karle, Madhur Behl, Venkat Krovi, and Rahul Mangharam. Autonomous

vehicles on the edge: A survey on autonomous vehicle racing. *IEEE Open Journal of Intelligent Transportation Systems*, 3:458–488, 2022.