Diploma Thesis Review
- supervisor -

Name of student: Burak Aydin

Thesis topic: Trajectory determination and control for autonomous racing

Supervisor: Doc. Ing. Martin Hromčík, Ph.D.

The goal of the diploma project was to investigate, design, implement and validate selected algorithms for determination of trajectory from visual data for the student autonomous formula races. The motivation comes from the fact that an action group on autonomous racing was established in 2019 at FEE CTU at the eForce student formula racing team.

The main result of the thesis is a set of approved fundamental procedures that can be used to estimate the vehicle offset from the path (centerline) based on the assessed relative positions of the left and right cones (distinguished by colors) in the field of view of an anticipated stereo camera system. The routines are programmed in MATLAB, as well as the comprehensive simulation environment which the student developed to evaluate the trajectory determination algorithms and validate their performance. I believe the procedures can be readily compiled into the onboard system of an autonomous formula once an instrumented prototype is available. As an additional result, the student investigated a selected model predictive control algorithm for dynamical stabilization and control of the vehicle; the single track model was used for this task.

Regarding consultations and cooperation with the student, the fact is that at the beginning the communication was rather tough for me and my recommendations and tasks were not addressed by the student. It improved significantly in the course of the time however; and the resulting thesis turned out to be very good in my opinion.

Based on the above arguments, my suggestion is **grade B, very good.**

2020/05/06

Date

Signature

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Master's Thesis Review

Prague, June 9, 2020

Title: Trajectory Determination and Control for Autonomous Racing
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The thesis presents a method for estimating a centreline of a path delineated by traffic cones, a race track of student formula competition. A lateral deviation from the centreline is estimated. The algorithm assumes the traffic cone position is given. The second part of the thesis proposes an MPC (Model Predictive Controller) to track the centreline in a lane keeping assistant fashion.

The thesis comprises 7 chapters. The first chapter provides a motivation, introduces a reader into the autonomous driving and racing, formulates the problem, and briefly reviews related literature. The second chapter presents the proposed centreline estimation algorithm. Chapter 3 summarizes kinematic and dynamic models of a vehicle. Chapter 4 describes the MPC controller. Chapter 5 presents the MPC controller tracking the estimated centreline. Chapter 6 shows simulations and Chapter 7 concludes the thesis.

To name positive points of the thesis, I would emphasise that the problem is practical and really occurs in the autonomous student formula system design. The author proved certain level of competence in implementing and testing the MPC controller in simulations. Some of the technical issues that needs to be resolved are well discussed. The proposed algorithm probably works to some extent.

On the other hand, the thesis suffers from several weaknesses.

1. The proposed centreline estimation algorithm is not presented clearly. The input to the algorithm (cone positions, vehicle positions) is assumed perfect, without any uncertainty or noise, which is naive especially when the cones are said to be localized by stereo-vision. Despite the unrealistic assumptions, it is unclear if data are fed to the algorithm sequentially or at once. The output of the algorithm is also unclear – Is it a continuous curve or a discrete set of waypoints? The pseudocode in Alg. 1 is not legible and would have required a major revision, since it is by far not reproducible.

2. Estimation of path curvature in Sec. 2.5 suggests that the discrete waypoints are taken. Nevertheless a scale on which the curvature is estimated is not revealed. The path cannot be always represented explicitly by function graph $\big(x, f(x)\big)$. This might be the reason of a large discrepancy between the ground-truth and the parabolic estimate in Fig. 2.14.

3. The experiments are not enough convincing generally in the thesis, both for the centreline estimation and for the MPC controller testing. An algorithm correctness needs to be proven, either mathematically or by a set of experiments that spans many possible cases of the input. Only a single instance in a simple track (an open arc) is shown in Fig. 6.1. The example of the deviation from the centreline in Fig. 6.2 is trivial. Set of more complex scenarios with various tracks with a possible ambiguity where the path goes should have been generated and the algorithm tested on it. The MPC controller is again shown on a single instance as well in Fig. 6.10. It is unclear why the curves in Fig. 6.9 are so wavy while the reference path seems to be perfectly smooth.

4. The thesis does not read well. There are many undefined references and symbols, unfinished sentences and typos. Symbols in the text are often not matching symbols depicted in figures which is particularly confusing.

In summary, I suggest assessing the thesis by

D – satisfactory.

Ing. Jan Čech, Ph.D.