Assessment of bachelor's thesis as supervisor

Title: **Platooning with Low-Cost Sensors**
Author: **Miodrag Ignjatović**
Supervisor: **Dr. Gaël Écorchard**

Fulfilment of Assigned Tasks

All the tasks that were possible to achieve have been fulfilled. One of the tasks concerning the use of GPS data could not be realized for practical reasons and because of the failure of other students working in parallel.

Resolution Methods

The student used the suggested method for the robot relative localization. The method was then adapted by him in order to improve its accuracy. The student then independently researched references about control law and path following for our use case and implemented the found algorithms.

Obtained Results

Both the reactive algorithm and the path planning algorithms show good results. The results of the path planning algorithm are especially promising though the behavior of the algorithm at hard corners is still open for improvements. It is also regretufl that the results are not show in a more quantitative manner. The implemented methods were tested mainly in a simulated environment. What is not shown in the thesis is that the student did also implement the methods on real robots. These results are given on the attached CD in the form of videos but there is no quantitative assessment of the methods applied on real robots, what would have been a big positive point beyond the assigned tasks.

General Comments and Conclusion

Student Miodrag Ignjatović worked almost autonomously on his thesis' subject. A lot of good work has been achieved but it was sometimes difficult to receive some feedback from the student. Some of the planned meetings were even missed by the student. The overall quality of the thesis could have been improved if the student had spent more energy on the subject since its beginning. The only question I have regarding this work is how good in terms of deviation from the guide's path and distance to the guide are the alrgorithms.

As a conclusion, I advise the commission to evaluate the presented bachelor's thesis with the grade

B - Very Good

Prague, February 3, 2017

Dr. Gaël Ecorchard
ČVUT, CIIRC

Assessment of the thesis by a reviewer (Posudek oponenta)

Reviewer: Ivo Herman

Student: Miodrag Ignjatovič

Platooning with low cost sensors

The thesis deals with an implementation of a simple platooning algorithm in the Robot Operating System (ROS). The author first designed a controller for a differential drive robot, then implemented a vision-based relative localization algorithm. In order to allow the following robot to take the same path as the leader, a path-following algorithm is presented. The data from the odometry and vision is then combined using the Extended Kalman Filter (EKF).

As such, this seems as a great amount of work. The author logically decided to build on available packages in ROS. Hence, the work done was mainly an interconnection of ready-to-use packages with some tweaks. This is in my opinion a good way how to work on a bachelor thesis and the report shows a good understanding of ROS and of the problem to be solved. The tools and methods used to achieve the results are therefore well chosen.

If I understood the thesis correctly, everything was only tested in a simulation environment. Although the thesis shows a photo of a test platform, I think this was not used at all. That is why I hesitate to state that the goals of the thesis were completely satisfied. Based on my experience, the path from a simulation to a real-world implementation is very long, especially when the sensor is vision based. So in my opinion the goals were only partially achieved.

It is very difficult to assess the results in the thesis, as there is not a single precise statement, not a single numeric value. Everything is written very vaguely, e.g., "some manipulation of covariance was required (p. 37)" (what manipulation?); "PID controller was tuned manually" (p. 22) (what is the resulting controller?). The same holds for the velocity control law (6), the filter (10), the EKF in section 9. (no model, no estimation of the covariance matrices, no initial conditions, sampling period, discretization, ...). This all makes the thesis unverifiable and does not provide the reader any insight. No one, except for perhaps the members of the IMR group who know the implementation details, will go into the source code and try to find the details. This is the major weakness of the thesis.

The simulation results in Section 10 are not convincing. The author did not provide any time plot (which is crucial for evaluation of the platooning), so the effectiveness of the robot following algorithm cannot be verified. I would like to see not only evolution of the distance between robots in time, but also the measurements by different sensors, the covariance of the measurements. The simulation setup was not described (the desired distance, duration of the simulation, camera resolution etc.). Some quantitative evaluation of the two approaches should be given.

Formally, the thesis is written with a good command of the English language and is reasonably well split in different sections. However, the thesis would have benefited from one more proofreading as it contains a lot of typos and missing words. This makes the reading sometimes difficult. The vague statements used all over the thesis make it difficult to distinguish whether the particular task was done by the author or by someone else (the package in ROS or author's colleague).

The references used in the thesis are mainly related to the ROS (except for two papers recommended in the assignment). I think that platooning with differential-drive robots is quite a common task in the literature. The author should at least mention some of these works and spend more time on the literature review. Moreover, the references are provided without a source (no publisher, no journal).

To summarize, the author has shown some understanding of the problem and the ability to choose suitable methods for solving it. However, the way the thesis is written does not allow to assess whether the tools really worked and whether they were used correctly. The fact that everything was (probably) done only in simulation makes me feel that the assignment was not completely satisfied.

I have to leave it to the committee to decide whether the system really worked. If it did, then a better grade than I propose can be given.

I propose the thesis to be classified by the grade **D** with 62 points.

Questions:

1) Can you describe the simulation setup in Sec. 10? Can you provide the time plots for both robots? I am mainly interested in the environment for the robots and the time plots.
2) Why there is a nonzero velocity for a zero error in Figs. 5.3.2 and 5.3.3? What delay did the additional filter CO add to the closed loop?
3) Could you please comment on the stability of the modification of the control law from the reference [4]?
4) Could you explain the use of EKF? Which model was used, what were the covariances and how was the algorithm changed when measurement by only one of the sensors was present?

In Prague, 24nd January 2017

Ivo Herman

Doctoral student, CVUT FEL