

I. IDENTIFICATION DATA

Thesis title:	Autonomous vehicle position data fusion
Author's name:	Bc. Tomáš Twardzik
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Control Engineering
Thesis reviewer:	Ing. Michal Sojka, Ph.D.
Reviewer's department:	ČVUT, CIIRC

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	challenging
<i>How demanding was the assigned project?</i>	
The project was challenging because the student has to deal with a physical platform and solve real-world engineering problems. In addition to that, he had to understand several domains (sensors, control theory, ...) and combine the information from them to one coherent work.	

Fulfilment of assignment	fulfilled
<i>How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.</i>	
I consider the assignment as fulfilled. Although the student mentions, that some parts of the solutions are limited or exhibit some problems, the amount of work done is extraordinary and the results are convincing.	

Methodology	outstanding
<i>Comment on the correctness of the approach and/or the solution methods.</i>	
The student first studied the technologies of the respective sensors and described them in great detail, including interesting facts about which sensors are currently used by key industrial players. Then he described theoretical basis of data fusion algorithms. The practical part builds on the theoretical one and describes how the sensors and algorithms are used on the developed platform. The author derives the mathematical model of the car and designs an Extended Kalman Filter for it. Finally, the implementation is evaluated on the data from the real vehicle.	

Technical level	A - excellent.
<i>Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?</i>	
The technical level corresponds to what I would expect in such a kind of work. I do not see significant problems. However, some parts could improved: <ul style="list-style-type: none"> For example, the author describes, that he modified operating system configuration and startup scripts, but there are no any details what was modified and how. People working on the project in the future might benefit from having that documented. Additionally, the description of system model in Chapter 8 could be improved. The state vector is first defined in a paragraph text an subsequent sections are slightly harder to follow. For example, it is not clear how the author "injects precise measurement of heading from HM GNSS receiver". Finally, at a few places, e.g. Figs. 7.3 and 8.4, the author presents some results, without any conclusion. The reader has to interpret the figures themselves and guess, which method provides better results. 	

Formal and language level, scope of thesis	B - very good.
<i>Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?</i>	
The thesis is written in good English and typeset with LaTeX, thus having good look. Language-wise, sometimes the author uses informal language ("I have tossed the term", "crudely divided", "little to none"). The thesis is longer than is usual (156 pages), but most of the content is interesting. With some effort, the text could be shortened, without losing any	

information; especially the Introduction chapter is unnecessarily wordy. From the typographical perspective, the author should learn the difference between the inch character "." and quote characters "...".

Selection of sources, citation correctness

A - excellent.

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

The thesis references over 90 sources and cites them well.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

I appreciate that the student has participated in writing two papers published at recognized conferences.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

The student conducted huge amount of work, from technology/literature review, over construction of mechanical parts to designing algorithms, implementing and evaluating them. All this is well described in the thesis and the results appear functional. The author acknowledges few limitations, perhaps the most significant is inability to run his algorithm on the vehicle in real-time. However, the thesis will definitely allow other students to continue in this work and complete the missing pieces.

I have the following questions for the student:

- Your GPS antennas are equipped with circular metal plates. Can you quantify how it improves the quality of received signals and quality of localization?
- You mention, that using a Wireguard VPN adds 30 ms of latency to RTCM data. How is the GNSS accuracy influenced by those RTCM communication latencies? Which latencies are acceptable? Is the use of public mobile internet (via 3G/4G/5G) sufficient w.r.t. achieved latencies?
- What do you think is the biggest complication in implementing your EKF for use in real-time on the vehicle platform?

The grade that I award for the thesis is A - excellent.

Date: **26.8.2022**

Signature: