# THESIS REVIEWER'S REPORT

## I. IDENTIFICATION DATA

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| **Thesis title:** | **LIDAR-Based Lane Tracking using Kalman Filtering and its Fusion with Camera-Based Lane Data** |
| **Author's name:** | **Daniel Veškrna** |
| **Type of thesis :** | **master** |
| **Faculty/Institute:** | **Faculty of Electrical Engineering (FEE)** |
| **Department:** | **Department of Control Engineering** |
| **Thesis reviewer:** | **Ing. Michal Sojka, Ph.D.** |
| **Reviewer's department:** | **ČVUT, CIIRC, IID** |

## II. EVALUATION OF INDIVIDUAL CRITERIA

**Assignment** — **ordinarily challenging**

*How demanding was the assigned project?*

The assignment lies in implementing well known algorithms and using them for parameter estimation from publicly available data sets. Only the 6th point gives the student freedom in selecting the algorithm or proposing a new one.

**Fulfilment of assignment** — **fulfilled with minor objections**

*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.*

Most of the assignment is fulfilled. The last (6th) point asking for fusion of lidar and camera-based data is not implemented and the text of the thesis mentions this possibility only theoretically in short chapter 5.

**Methodology** — **partially applicable**

*Comment on the correctness of the approach and/or the solution methods.*

To estimate line parameters, the author proposes two basic methods, Kalman filter (KF) and RANSAC, and their combination. Both methods could be improved.

The KF is used in an unusual way and in my opinion, its use does not bring any advantage over, e.g., linear regression. KF usage is shown in Algorithm 3 on page 29. Both prediction and update steps are computed for individual points from a single LIDAR scan. The prediction step does not change the estimated state at all due to the state transition matrix being unitary. The only advantage of KF over linear regression would be the transfer of estimates between frames in the sequence. But here, it would beneficial to predict the change of the parameter estimation based on the known movement of the vehicle between the frames, but this information is not utilized by the student in any way.

The RANSAC algorithm was applied in its basic form. The conclusion was that the results are "unreliable" due to higher probability of choosing all points closer to the ego vehicle. I believe, the result could have been much better if the points are chosen not with uniform probability.

**Technical level** — **C - good.**

*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?*

The algorithms and evaluation scripts are implemented mostly in Matlab, one script is in Python. The developed functions (about 1000 lines of code) are documented and easy to read. The results of the RANSAC method contain performance evaluation, but the performance of the KF is not mentioned numerically. The implemented algorithms are evaluated only on two 8 seconds long sequences, which is too little for serious evaluation. The author writes that more sequences were used for development but the results are not mentioned in the thesis. It is understandable, that absolute error evaluation required manual annotation of the sequences and thus it was conducted only on a limited set of them, but for other evaluations more data should have been used (the used data set contains more than one hundred scenes). However, despite not testing the algorithms on more sequences, data visualizations shown in the thesis illustrate the proposed methods and discovered weaknesses well.

**Formal and language level, scope of thesis** — **A - excellent.**

| *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?* |
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| Formal and language level of the tests is the strongest part of the thesis. The thesis is written in English, it is easy to read and is organized in a logical structure. The algorithms and their results are well explained and discussed. The figures are good and illustrate nicely the described matter. Only Figure 3.12 is unnecessarily confusing because the color of the points corresponds to the y-coordinate and is redundant. |

| **Selection of sources, citation correctness** **A - excellent.** |
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| *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 author selected good sources and summarized the related work nicely in Chapter 2. All references are mentioned correctly, with the exception of [16], which includes unnecessary "keywords". |

| **Additional commentary and evaluation (optional)** |
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| *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.* |
| It is unfortunate that the methods deals only with estimation of parameters from pre-filtered point set and is not directly applicable to arbitrary LIDAR data. |

**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 thesis presents several algorithms to estimate road line parameters from LIDAR data. The presented algorithms are able to achieve this goal, but the results could have been better, if the algorithms are applied better or more sophisticated methods were used. The evaluation of the algorithms is well described in the text, but could have been performed on more data to give more significant results. Unfortunately, the results were not compared with any other method found in the literature.

I have the following questions for the student:

1. What was the performance of the KF compared to RANSAC?
2. How would you incorporate knowledge of vehicle movement between frames to improve the prediction in subsequent frames?
3. Would changing probability of selecting points for RANSAC improve its performance?
4. Fig. 3.15 shows a problematic case for KF. However, the result depends on lane sorting of the points, which is not shown in the figure. Could other lane sorting algorithms provide better results?

The grade that I award for the thesis is **C - good.**

Date: **Click here and enter the date.**

Signature: