Bachelor thesis evaluation "Motion Planning for Autonomous Car Manipulator"

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The goal of the thesis was to design, implement and test methods capable of planning and executing the movement of an autonomous vehicle. The purpose of the vehicle is to transport passenger cars from a production line to a storage area. The primary focus of the thesis was to implement a basic path planning method capable of executing manoeuvres in narrow spaces, expected in crowded parking lots.

During the work that led to the system's implementation, the student worked systematically and autonomously, making steady progress towards the goal. He consulted his work regularly and contributed to activities that did not concern just path planning but also simulator design and environment model building. Moreover, he had to overcome several technical issues related to the implementation of the methods in a real vehicle. The software implemented is mature enough to be deployed in a proof-of-concept logistical system at the Skoda Auto manufacturing plant at Mlada Boleslav. Unfortunately, the experiments presented were limited due to the parking lots filled beyond the operational capacity as a result of the component shortage.

The structure of the thesis itself follows the aims as set in the thesis assignment. The student explains the background of the task, provides an overview of the state-of-the-art, presents the investigated methods and their applicability. Finally, the student evaluates the deployment of the investigated methods in the simulated robot and the actual system. While the work performed was rather extensive, the thesis itself was completed in relative haste, which resulted in a number of technical deficiencies of the thesis text. However, these deficiencies do not affect the thesis results, and the correctness of the solution presented. While the thesis has certain drawbacks, the primary goal of the thesis was achieved, and I classify the work performed as

B - very good.

Prague, Czechia,
January 24, 2022

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THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Motion Planning for Autonomous Car Manipulator**
Author's name:	**Vadym Ostapovych**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of cybernetics
Thesis reviewer:	Ing. Vojtěch Vonásek, Ph.D.
Reviewer's department:	Department of cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — ordinarily challenging

How demanding was the assigned project?

The assignment requires basic knowledge of control techniques that are covered by standard bachelor courses. Additionally, knowledge of simple motion planning was required.

Fulfilment of assignment — fulfilled

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.

Student tested several basic control strategies and motion planners in simulation and selected the most promising ones for a real-world experiment. HW experiment with the physical robot was performed. All guidelines were fulfilled.

Methodology — correct

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

The methodology is correct. Student first analyzed kinematic model of the vehicle and relevant basic control strategies (Point-top-point controller, Pursuit Controller, MPC and Pose controller). Basic motion planners (Straight-line planner and RRT-based planner) were also considered. Student then created model of the robot for Gazebo simulator and used point-cloud data to model the environment. He tested the control strategies in the simulation to evaluate the influence of their parameters and to select most promising (fast and precise) controller. Similarly, motion planners were tested in the simulation. Selected techniques were also tested on the real robot.

The HW experiment (Section 5.4) is quite short. It seems that only a single run was performed. There is no description of how fast was the planner (planning time is not given) or what is the time to execute the trajectory. More trajectories should be evaluated, e.g. with different goal positions. The HW experiment is supposed to be in a 'narrow space of the robot', but it is not described why the space is 'narrow'.

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 utilized RRT (Rapidly-exploring Random Tree) planner (Alg. 2, page 20) is presented in a slightly incorrect way: random states X_rand should be always generated in the whole configuration space, i.e., without testing if they are collision-free or not (the condition If "X_rand is not collision-free" can be omitted in Alg. 2). In the case of the almost empty workspace considered by the student, it's not a big mistake, but generally, RRT does not work this way. Second, author claimed that "Djiskra algorithm" is used for finding the shortest path in the tree (Section 5.2.3, page 43) (student probably means "Dijkstra's algorithm". There is no need to employ this graph-search method in the case of RRT.

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Can you explain why and how do you search for the shortest path in RRT using Dijkstra's method? Can you utilize a different (a faster) technique to retrieve the path?

The computation time for RRT (and Dubins-RRT) is not given. Can you show how fast is this planner (e.g., show the total planning time or number of nodes per second).

Student developed a technique to estimate the number of samples N_it (Alg. 2) based on the distance between start and goal. It would be suitable to also test this technique, e.g., show the probability of finding solution (trajectory) for a given amount of samples to verify whether the proposed technique works as supposed.

Formal and language level, scope of thesis D - satisfactory

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?

The thesis is divided into 6 chapters that logically lead the reader through the work. The text is readable with a very good level on English. While the technical level of the work is quite good, the text itself contains numerous grammatical errors ("it's" → "its" (the sentence before Eq. 5.3, page 34), wrong name of "Dijkstra's method" (page 45, page 49), typography issues (e.g., using breaking space before citation (example: section 2.4, "Latombe [13]", or referencing without a space at all (example: "Pin[15]", Section 2.4)) and non-referenced images (the figure on page 30). Many images contain graphs or illustrations with small unreadable fonts: (e.g. Fig. 4.2, 5.1-5.9, 5.12). On the other hand, more illustrations would be beneficial in Chapter 3 to better describe the kinematic model (i.e., to show the coordinate system of the real robot, reference points, main axis etc.). Illustrations showing relationship between robot pose and a trajectory would also help to understand what he means. Inappropriate fonts are used for sin/cos/tan functions (e.g., Eq. 3.1-3.3, and most of equations in the Chapter 3). Wrong parentheses are used in Eq. 3.62 for angles.

The text contains few incorrect claims (e.g. "polygons in the topological maps" (end of Section 2.1, page 3) – there are no polygons on the topological maps!). The abbreviation AGV (page 3 bottom) is not defined, though the reader may guess what is it. The term "most optimal" (the first sentence after Eq. 3.36 (page 22)) should not be used.

Selection of sources, citation correctness C - good.

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 cites basic literature from robotics. The original paper where RRT was proposed is not cited at all. The paper [16] from 2001 is described as "The new approach to motion planning.." (Section 2.4.), which is slightly misleading in 2022.

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.

It is obvious that the student is able to study state-of-the-art methods, implement them and adapt for a particular robotic system, test them and even integrate the developed methods into a bigger framework. Unfortunately, much less effort was spent on the text of the thesis, which is under the average level of bachelor theses of OI/KYR students.

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

Date: 01/17/22

Signature: