ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Robotic Motion Planning Guided by Demonstration**
Author's name:	**Kovář David**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Dr.-Ing. Jan Kristof Behrens
Reviewer's department:	Czech Institute of Informatics, Robotics and Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — **challenging**

The topic of using demonstrations for robotic motion planning is challenging because it requires creative additions to complex algorithms. The benchmarking must be designed carefully to capture a relevant set of planning problems. The effect of algorithmic changes is often not easy to attribute. Changes must be made carefully to not inadvertently destroy properties such as (probabilistic) completeness.

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

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

1) Three different parametric tasks with different properties are introduced. That gives, in general, much opportunity for benchmarking. However, I observed a symmetry in the parameter space that is partly redundant. This would lead to repeated experiments in a systematic benchmarking.
2) The existing random sampler was extended to use whole demonstrated object trajectories instead of only pick-up and place locations. The extensions leads to a probabilistic sampling of end-effector poses around the observed trajectory while correctly considering the object grasp. The sampling is controlled by fixed parameters for the translational and rotational components.
3) The demonstration creation is described on less than half a page and leaves open some questions. The technical challenges are not discussed. How are the demonstrations post processed to contain all the data? This would require, for example, a precise calibration of the camera pose relative to the robot and furniture positions.
4) The proposed approach is evaluated on two of the three tasks against reasonable baselines.

Method of conception — **correct**

Assess that student has chosen correct approach or solution methods.

1) The parametric creation of benchmark scenarios is a good approach. It is not clear, how many scenarios were used and how exactly the parameters were varied. It would have been nice to employ a principled approach to scenario generation, e.g., [Zhou21].
2) The proposed sampler is not probabilistically complete for small noise parameters values and the guidance is weak for large values. It would have been probably smart to dynamically increase the noise parameters when the area around the demonstration is sufficiently sampled. Alternatively, complete random samples could be mixed in. The identification of the noise parameters utilizes a very rough discretization. A refinement around the selected parameters or the use of a method such as [Jaqu21]. The author did not address how the IK problem is solved for the redundant robots (Panda and KUKA iiwa). It would be important that the nullspace Is utilized to achieve robust solver behavior.
3) The description of the demonstration procedure is too short to be evaluated. I believe that it can be done, See comments above.
4) The comparison was designed quite well. The time and path length metrics should be reported together with the success rates and iteration numbers. The time complexity could be analyzed using the Python profiler. I find it not

surprising that the proposed method is slower per iteration, because of the solution of an IK problem per iteration (which was correctly identified).

[Zhou21] Y. Zhou, S. Booth, N. Figueroa, and J. Shah, "RoCUS: Robot Controller Understanding via Sampling." arXiv, Oct. 14, 2021. Available: http://arxiv.org/abs/2012.13615
[Jaqu21] N. Jaquier, V. Borovitskiy, A. Smolensky, A. Terenin, T. Asfour, and L. Rozo, "Geometry-aware Bayesian Optimization in Robotics using Riemannian Mat\'ern Kernels." arXiv, Nov. 02, 2021. doi: 10.48550/arXiv.2111.01460.

Technical level **A - excellent.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

Fulfilling the assignment and demonstrating it on a real robot with real demonstration data requires excellent technical knowledge. Future improvements of the method will be enabled by the foundation laid in this work.

Formal and language level, scope of thesis **C - good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The notation is mostly correct. The rate of language mistakes is too high. The typographical layout is good.

Selection of sources, citation correctness **B - very good.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The citation style is good. [Hart et al] is twice in the Bibliography (both citations in the same line on page 3). The construct "… work [citation] uses" is not that nice. The sources were selected correctly. Images and text citations were marked appropriately.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

The student took on a challenging topic where it is not clear in the beginning that a clear improvement can be achieved. He proposed a promising algorithmic extension that achieved better performance in the number of iterations and the sometimes in the success rate. He formulated a well structured thesis that gives the reader a good impression of what was done. In the discussions, I am missing more clear conclusions and explanations. The rate of language errors is too high. As noted above, there are ways to improve the work done.

Q1: Under which circumstances can a demonstration be transferred to another planning problem?

Q2: How would the constraint graph in Fig. 2.4 look like if the contact surface of the cylinder in contact with the table was part of the state?

I evaluate handed thesis with classification grade B - very good.

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

Date: **24.4.2023**

Signature: