REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Visual Navigation using Deep Reinforcement Learning**
Author's name:	**Jonáš Kulhánek**
Type of thesis:	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics, FEE CTU
Thesis reviewer:	Jens Kober
Reviewer's department:	CoR, 3mE, TU Delft, Netherlands

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	**challenging**
Evaluation of thesis difficulty of assignment.	

The assignment was about learning robot navigation in unknown environments based on raw camera images. The project significantly extends the state of the art by developing a deep reinforcement learning approach that can navigate in continuous spaces in a realistic simulation.

Satisfaction of assignment	**fulfilled**
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.	

The candidate fulfilled all the points of the assignment and exceeded the expected level. He reproduced several approaches from the literature, combined them, extended them, and thoroughly evaluated the novel approach.

Method of conception	**outstanding**
Assess that student has chosen correct approach or solution methods.	

The candidate has implemented several deep reinforcement learning algorithms including A3C, A2C, ACKTR, DQN (DDDQN) and reproduced the results of the UNREAL algorithm.

The candidate prepared Docker and Singularity images together with scripts allowing him to run AI2-THOR, House3D, Minos and DeepMind Lab 3D environment simulators on a GPU computing cluster.

The candidate worked on visual navigation, he experimented with different algorithms, different reward functions and different deep neural network architectures.

The candidate proposed and implemented a method for visual navigation in indoor-scene environments that extended batched version of A2C algorithm with auxiliary tasks for visual navigation, increasing its performance and allowing the network to be initialized using supervised learning. He proposed an efficient network architecture and proposed a way to boost the performance of the algorithm using transfer learning. Through an extensive simulation study with a set of realistic indoor environments, he has shown that his method outperforms state-of-the-art algorithms.

The candidate was very methodical in his approach and came up with a sound new approach that has been thoroughly evaluated.

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.	

The candidate clearly has gained an excellent knowledge of reinforcement learning and deep learning. He also has learnt how to do experiments properly and how to write scientific reports/papers. The level of detail is right for the thesis specialty, the state-of-the-art and the contributions of the candidate are very clearly explained. The report is free of scientific errors. Overall the technical level of the report and the attached paper is excellent.

Formal and language level, scope of thesis	**A - excellent.**
Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.	

The thesis is very well structured and very well written. I did not spot any (major) language issues. The use of figures, equation, tables, etc. is at the right level and helps the reader to understand the material. All these items are of high quality.

Selection of sources, citation correctness   **A - excellent.**

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 literature overview is thorough. Own results and results from the literature are clearly distinguished. The citations fully comply to the established standards. Also see "technical level" above.

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.

The thesis resulted in an international conference submission, having the code on GitHub is a great contribution to the open scientific community. The thesis went beyond the initial goals by establishing a sound, novel approach that has been thoroughly evaluated.

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.

Overall an excellent thesis, both in the presentation/writing and in the development of a new approach and its thorough evaluation.

Questions for defense:

- What would need to be changed to apply this approach in a real-world scenario?
- What are the limitations of this approach?
- What are the minimum requirements in terms of features of the environment? E.g., navigating in a house where every room looks exactly the same will be infeasible.
- Would it make sense to extend this approach from purely visual input to also including odometry and/or history?

I evaluate handed thesis with classification grade **A - excellent.**

Date: **8.5.2019**   Signature: