



I. IDENTIFICATION DATA

Thesis title:	Exploratory action selection to learn object properties through robot manipulation
Author's name:	Andrej Kružliak
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Mgr. Matěj Hoffmann, Ph.D.
Reviewer's department:	Department of Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	challenging
<i>How demanding was the assigned project?</i>	
This project was challenging as it required a demanding theoretical part applying the concepts of probability theory, information entropy etc. as well as a practical part with experiments in a robot simulator and in a real setup.	

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>	
All the parts of the assignment were fulfilled. Inference in the Bayes network was performed manually; application of one of the frameworks like STAN remains future work. The experiments - "virtual", in simulation, and in real - are somewhat preliminary, but given the overall extent of the thesis, they suffice.	

Activity and independence when creating final thesis	A - excellent.
<i>Assess whether the student had a positive approach, whether the time limits were met, whether the conception was regularly consulted and whether the student was well prepared for the consultations. Assess the student's ability to work independently.</i>	
The student was active, thorough, and independent during the work on the thesis. He received ample feedback from the supervisor as well as from partners within the IPALM project (Prof. Ville Kyrki in particular) as well as assistance regarding the ROS and the simulation environment from the supervisor specialist. He could plan his time to accomplish all the goals of the thesis.	

Technical level	A - excellent.
<i>Is the thesis technically sound? How well did the student employ expertise in his/her field of study? Does the student explain clearly what he/she has done?</i>	
The thesis is technically at an excellent level. With planned extensions, this will become a solid contribution over state of the art.	

Formal level and language level, scope of thesis	A - excellent.
<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>	
There is a lot of theory and mathematical formalisms that the student correctly used, described and appropriately visualized. The thesis is very extensive but a very good standard of language and formatting is maintained throughout the text.	

Selection of sources, citation correctness	A - excellent.
<i>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?</i>	



THESIS SUPERVISOR'S REPORT

The Related work reported in the thesis is adequate, even if largely based on the supervisor's recommendations - the student did not have time for an extensive independent study of the literature. Online resources as well as work from his colleagues (e.g. Michal Pliska) are properly cited and credited. There is an openly accessible repository hosting the code developed in the context of the thesis.

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.

The student proved to be able to independently study and apply knowledge from different disciplines and demonstrated theoretical as well as practical skills. The final document has a very high standard throughout.

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.

This is a truly exceptional Bc. thesis and it constitutes a very solid basis for turning it into a publication.

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

Date: **1.6.2021**

Signature:

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Thesis reviewer:	Radoslav Škoviera
Reviewer's department:	Department of Robotics and Machine Perception, CIIRC, CTU in Prague

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	challenging
The assignment topic was very challenging. Neither of the two main topics – robotic manipulation/grasping and Bayesian networks, is easy. Let alone putting them together and dealing with measurement uncertainties.	

Fulfilment of assignment	fulfilled
A part of the last step in the assignment is not fulfilled but this was due to a lack of a necessary external prerequisite (as explained in the work) which is not the student's fault. I think it is a pity that only two material properties were used and that the BN was not implemented in a good framework (and thus some useful BN features are missing). However, this was not strictly required in the assignment, thus I must conclude that the assignment was fulfilled.	

Methodology	correct
The methodology of the chosen approach is, in my opinion, sound. I would appreciate a more thorough evaluation and, as also stated by the student in the thesis, the proposed method suffers from the lack of message passing algorithm in the BN. However, I think, what was done is sufficient for the scope of a bachelor's thesis.	

Technical level	A - excellent.
The thesis is technically sound. The student have shown a good knowledge of the Bayesian networks and dealing with various uncertainties in measurements and data gathering. The proposed method is explained very well.	

Formal and language level, scope of thesis	A - excellent.
The work is overall well written with only minor typos which I find inconsequential to the quality of the work. I would appreciate a slightly better structuring of the work. Certain sections feel a little out of place, e.g. density and Young's modulus estimation sub-sections in section 3.1.3, which is concerned about simulation setup. Also, it would be nice to introduce the overall proposed approach at the beginning, so that the reader can keep this in mind while reading explanations about various methods. Something like figures 3.22, 3.23 but more general and for the whole proposed system.	

Selection of sources, citation correctness	B - very good.
All citations were used well. The related work section is, in my opinion, lacking in sources from closely related topics of interactive perception and information gain, e.g., Otte, Stefan, et al. "Entropy-based strategies for physical exploration of the environment's degrees of freedom." 2014 IEEE International Conference on Intelligent Robots and Systems. Such papers could have been used as an inspiration for a more sophisticated measure of information gain (even if it was used in a different setup). I think a little bit more literature research should have been done.	

Additional commentary and evaluation	
I commend the student for taking on a relatively difficult topic of working with real robotic manipulators and Bayesian networks being used in practical scenarios. Although, I must say that the final implemented version is a bit disappointing	

as opposed to what was “sold” at the beginning of the work. This includes a very small number of real-world materials (only 2), low number of actions (2), and simplicity of the actually implemented BN, which involves only two properties and has limited inference capabilities. This somewhat limits the resulting contributions. For example, in my opinion, it would be difficult to estimate the actual functionality or usefulness of the method in a more complex setup, from the provided results.

However, I understand that for the scope of Bachelor's thesis, what was done is sufficient. I would suggest to clearly state what is going to be actually implemented early on, so that the reader is not disappointed at the end. Now, I hope that the student continues in this work on his master's thesis and is able extend it to a more complex environment. Both, the topic and the proposed solution are very interesting and with more work could result in a great scientific contribution.

Nonetheless, the theoretical part of the work is very well written with clear and in-depth explanations of all the used algorithms. The testing was done at three levels of “realism” which allowed for separate testing of individual parts of the proposed method, which is a very good approach.

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

The explored topic is very interesting and quite difficult. Unfortunately, few relatively easy extensions were not explored (better information gain, more materials/properties). However, with regard to the requirements of a Bachelor's thesis, the amount of work done and the theoretical knowledge required to do this work is, in my opinion, more than sufficient.

Questions:

- 1) At page 5, the student states that “the functionality of the proposed action selection algorithm does not significantly change with scale” as a justification for a simplification. While this might somewhat hold on theoretical level, what about computational complexity issues that arise with scale? (e.g. tractability of large BNs). **Do you think that the approach would be still usable with a large number of properties and materials?**
- 2) As stated in the work, quantities used in mode 1 and 2 are from different domains. This, perhaps, resulted in their naïve summation (mode 3) being worse than the best of those two. A very simple and straightforward improvement, often used when mixing quantities from different domains, would be to use a weighted sum. I wonder why wasn't this option, or any other, explored. It is also not mentioned in future work. **Can you briefly comment on the possibility of more complex information gain formulas being used in this setup? Or do you think the current approach would be sufficient?**
- 3) This is just a comment – in section 4.2, you are saying that “creating more original materials with clear differences in properties is of great difficulty” as a reason to only use 2 materials in the simulation experiments. I think it would be also beneficial to have more original materials without clear differences and see what would happen in these cases.

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

Date: **1.6.2021**

Signature: