Assessment of Bachelor's Thesis as an External Examiner

Title: **Playing chess with KUKA robot using linguistic instructions**
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Fulfilment of Assigned Tasks

The student's tasks consisted in implementing a chess playing robot without prior work from other students or employees. These tasks were all fulfiled appart from the optional task of incorporation of an automatic chess playing algorithm. The major part of the work consisted in incorporating readily-available ROS packages. The development of the chess logic part seems to have involved a lot of programming by the student but what is missing here is a justification of the reason why open-source libraries have not been used for this purpose, though such appropriate libraries seem to exist according a quick web search.

Resolution Methods

The extrinsic calibration method was carried out with OpenCV's solvePnP function. Though this is completely appropriate, the obtained results are quite bad and seem to indicate bad input for the function call or bad use of the function's outputs. The results of the second calibration, though better than the first ones, could not be used as is, as an affine transform was still needed to correct the marker positions. At this point, it seems that a 2D loop-up table would have been easier to use because it would have presented the advantage of working with an uncalibrated camera. The results of this second calibration with the affine transform are not given though. They are solely commented with the expression "satisfactory results".

The determination of the possible chessboard position relative to the robot has been carried out thanks to the working envelope given by the robot manufacturer. At this point, by mentioning kinematics model and Denavit-Hartenberg parameters, the student confuses the reader by making him/her think that a more complicated method was used.

The work makes heavy use of the ROS framework. It is then questionable why the student did not use the well-tested coordinate transform function of ROS's tf2 package to transform coordinates rather than implementing his own functions.

Obtained Results

The student was able to implement a complete chess-playing robot. The original idea of using some object recognition and localization of marker-less objects with a depth camera had to be simplified to 2D marked object localization but such a task would have been very challenging for a bachelor thesis. The developed framework will probably provide a good start for future works.

The major result of the work are the algorithm and the setup themselves. The presentation of quantitative resuls is rather short as it starts at page 43. Some of the presented results are unclear to me. The test called "first round of testing", for example, seems to me to be a pure test of the robot accuracy as the student does not provide a hint of what

could have failed in the back-and-forth robot moves. A similar remark applies to the test presented in Figure 4.15.

The student presents some results of the marker detection. The results presented there are quite surprising given the difference between Table 4.5 on the one side and Tables 4.7 and 4.8 on the other side. An explanation is given about lightning conditions, which may be correct, but a test confirming this hypothesis was not carried out, though it does not appear to me that such a test would be difficult to carry out, possibly with a smaller number of configurations. I was missing a zoomed-in image of a marker that would have allowed me to better assess the camera resolution relative to the marker size, or at least the information of the marker size in pixels.

The presentation of the tests of the language recognition algorithm are also not complete. I missed some important information there such as whether testers were native speakers or which engine was used from the several engines mentioned in Chapter 3. A mention of the algorithm training process is also missing there. It is for example unclear whether the algorithm was trained separately for each tester.

Practical Requirements

The thesis is very well presented and figures are clear. The quality of some of the figures could have been improved though by using vector graphics image rather than bitmaps. The English is mostly clear appart from a few sentences but a proof-reading would have helped avoiding classical language mistakes made from Czech speakers.

The number of references is appropriate but most of them are links to web pages. The thesis would have gain more weight by augmenting the number of citations of journal or conference papers which is a mere seven. The last citation is incomplete because it does not mention the type of reference. Bibliographic belongs to the main part of the thesis not into the annexes.

Some part of Chapter 3 could be shorten as they are not used further in the manuscript, e.g. the robot kinematics and the description of the internals of language recognition algorithms, or they do not provide usefull information to the reader, e.g. the listings of ROS types and some details about the Eigen library, which I consider to be implementation details.

The electronic version of the manuscript has a different page numbering as the paper version.

General Comments and Conclusion

The primary goal of the thesis is achieved and the student carried out a large amount of work. The thesis is clear a well-written. It is well structured, though some parts could have been shorten in favor of other ones such as the chapters about related work and the quantitative results.

As a conclusion, I advise the commission to evaluate the presented bachelor's thesis with the grade

B - Very Good.

Prague, May 31, 2019

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