Assessment of Masters' Thesis as an External Examiner

Title: **Probabilistic Gesture Control for a Robotic Arm**
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Fulfillment of Assigned Tasks

The assigned tasks correspond both to a high level of theory and technicality. All assigned tasks were fulfilled including the last optional one.

Resolution Methods

Two main approaches are used for the gesture recognition. The first one is a deterministic approach and the second one a probabilistic one. Both methods use the processed frame. It would have been interesting to study the use of probabilistic methods on the raw frames from the sensor, or, at least, the use of the processed frames rather than raw frames in probabilistic methods should have been justified. The output types of both deterministic and probabilistic methods could have been united by using a floating point number with 0 for false and 1 for true in place of the boolean.

With the deterministic method it is not clear what is the advantage of using Euler angles rather than the direction vectors directly. From what I understand, the relative direction vectors between first and last bone, **oc**, is computed with the following chain: bone direction vector, then Euler angles, then quaternions. **oc** could have been computed directly from the direction vector of each bone. Moreover, Eq. (6.2) is unclear as the multiplication of two quaternions is a quaternion and not a number between 0 and 1.

The overall resolution method seems appropriate. The emphasis should probably have given more on the probabilistic methods. There is no mention of the use of deterministic methods in the thesis' assignments but I suppose that their use has been discussed and agreed with the supervisors.

In section 6.3.2, for the "finger touches" gesture wouldn't the condition that the movement must be under a certain velocity threshold for a certain time improve the robustness of the detection? Because of this absence and the fact that the velocity does not appear to be filtered this detection looks fragile.

In the same section, the definition "circle direction angle" should be given.

In Section 6.4.1, paragraph "Network layout", it is not clear from the text whether the drop-out regularization is not present at all or not presented in the manuscript. The thesis is not accompanied with the source code so that an interested person cannot find this information there.

In Section 6.4.3, it is stated that the input for the dynamic gesture recognition with dynamic time warping are the processed frames rather than the raw frames because the number of frames is inconsistent. However, the data processing to obtain processed frames from raw frames is purely geometric. This is something that Petr should clarify during his defense.

Obtained Results

The thesis contains a lot of interesting experimental results. In a general manner, the results look convincing and show the success of the work.

There are some mentions of the accuracy of the sensor itself in Section 5.2.1 but, at first, there is a contradiction of the last paragraph of this section stating that a "turned

down" hand reduces accuracy and later on that it is advised to keep the hand in the "direction down", and secondly, intuitively, a hand rotated to the side is probably also difficult to detect. An image here would have help to differentiate between good and bad hand positions.

The three lines Figure 6.9 are not explained.

In Section 6.4.3 I didn't understand which of the methods has a computation time of 8 s.

In Section 7.2, Figure 7.8 an explanation is missing to explain the difference between the left-hand-side and right-hand-side plots. It should also be explained here if the physical robot is included in this result and, if not, why the inverse kinematics does not compute a precise path to the goal.

Practical Requirements

In a general manner the thesis is well presented. However, a lot of language mistakes render the text comprehension sometimes difficult.

Some details could have been improved for a better readability of the work, e.g. in Eq. (3.2), the same variable N is used for both the percentage of execution and the robot's degree of freefom one paragraph above this. Also, some reference are missing, as in pp. 17 and 19, or probably refer to the wrong element, e.g. "in the Lst.$\dot{3}$.2" p. 19, "In next S. 6.3" p. 40, or "in the previous S. 6.3.1" p. 41, and at least two others. Some figures are not cited in the text, e.g 5.6, 6.3, 6.13. Algorithm listings should have been written in a language-neutral manner. If this is not possible, they should not include variables which are not explained, such as `np` or `pm`.

Authors of reference 2, 31, and 43 are not formatted correctly. Reference 29 should not be considered as a reference as it is only an image from the web. Reference 36 does not respect the proper citation as required by the authors themselves, moreover, the authors of PyStan ask to also cite Stan and this is not done. The type of reference is missing in [45].

General Comments and Conclusion

The primary goals of the thesis are well achieved from the theoretical, practical and experimental point of views. The results show a large range of realized work. The functionality of the developed software was proven by having untrained people being able to use the system and drive the robot, so that I believe that the work will be useful for further development by the Team. The manuscript is well structured and presented but some language incorrectness render its reading difficult at some places.

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

B - Very Good.

Prague, June 9, 2021

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