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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Grigory Yashin

PhD Program: Engineering Systems

Title of Thesis: Development of group of flying robots with multifunctional robotic limbs aimed at operations in cluttered environments

Supervisor: Associate Professor Dzmitry Tsetserukou

Name of the Reviewer: Hiroyuki Kajimoto

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:** Hiroyuki Kajimoto **Date: 11-11-2020**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

• Brief evaluation

This paper aimed to improve the functional efficiency and control methods of a drone with robotic limbs. Two robots were developed for this purpose.

The first, AeroVR, is a quadcopter equipped with 4DoF manipulators to enable it to operate in the air. The second, DroneGear, is a hexa-rotor with four 2DoF legs that can land on uneven surfaces and move to a desired position.

The contents are sufficient as a PhD thesis.

• The relevance of the topic of dissertation work to its actual content

This paper summarized the question of robotic limbed drones to two sub-questions: "How can an operator comfortably remotely control an aerial manipulator?", and "How to make UAVs equipped with landing gear walkable through structural improvements?" and each is resolved in chapters 3 and 4. This methodology is reasonable.

• The quality of publications

There are two IEEE Transactions. He has also presented at prominent international conferences (ICAR, Haptics Symposium). Therefore, the quality of publications is sufficient.

• Questions and suggestions for final defense

In the following, let me discuss some aspects of this thesis that could be improved.

In Chapter 3, I would particularly like to see a discussion of viewpoint positions, i.e., third and first person viewpoints. Currently, it is explained that the camera attached to the end of the arm is the first-person view and the VR image is the third-person view, and only a limited comments from the users are listed.

However, the issue of viewpoint is quite important in teleoperation. In many cases, a robot that moves remotely can only create a first-person view. However, the first-person view is often insufficient for smooth work, and it has been pointed out that the "third person view from slightly behind" is more important. For example, Inami et al.'s study ensures a pseudo third-person viewpoint by using "images from the past in time".

https://www.youtube.com/watch?v=cu9w_UUaClY

In this experiment, a third-person viewpoint was mainly used, and I'm wondering if any inconsistencies occur with respect to the position and orientation of the hands. For example, when you move your hand back and forth, does the drone's hand move left and right in a coordinate rotation? In other words, I would like to know the relationship between the world coordinate system, the user's local coordinate system, and the drone's local coordinate system.

Also, I would like to hear "why" the visual system is the way it is now proposed. Overall, there seems to be little description of the visual system considerations. On the other hand, it is also necessary to discuss whether it is possible or realistic to use such a third person perspective in real scenarios.

Three tactile interfaces were proposed for remote control: the first one using a Vive controller, the second one using a transducer on the fingertip + IMU on the instep and arm, and a bending sensor on the hand, and the third one using an IMU sensor on the shoulder and bending sensors on the elbow and wrist. However, there are no photos available for this third one. Also, there does not appear to be any mention of the third one in the user study. Could you explain which one was used for the user study.

In the conclusion of chapter 3, it stated that one of the major drawbacks of the VR controller compared to the IMU-based interface is the need for an external tracking system. However, even though it is certainly true for the Vive, there are already many products that do not require an external tracker, such as the Oculus Quest, so this argument should be weakened. Rather, if possible, discuss how being IMU-based is "inherently" advantageous.

With respect to chapter 4, the illustration of the whole paper in chapter 1 (Fig. 1.5) seems to state that chapter 4 also contains design related to human factors, namely GUI and Visualization. However, Chapter 4 does not seem to contain such a topic. If this is the case, I think it is necessary to revise Fig. 1.5 (or to add an experiment on human factors in Chapter 4).

Provisional Recommendation

☑ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*