Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Yuri Sarkisov

PhD Program: Engineering Systems

Title of Thesis: Design, modeling, and control of cable-suspended aerial manipulator

Supervisor: Associate Professor Dzmitry Tsetserukou, Skoltech

Co-advisors: Dr. Konstantin Kondak, DLR; Dr. Christian Ott, DLR

Name of the Reviewer:

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 15-01-2022**

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

- ✓ The thesis covers fairly wide and complete array of topics, encompassing design, modeling, control and real experimentation of SAM. The thesis is certainly of high quality and also with very good organization.
- ✓ The proposed methodologies to solve the problems are technically sound, and their level also comparable to those of top-notch research/state-of-the-art results. All other aspects of the thesis and the author are also satisfactory.
- ✓ The followings are some comments on the thesis from my reading:
  - It appears that the rotors are unidirectional. Further, the winch actuation is also unidirectional (only via tension). What would be the implication or limitations imposed by these constraints on the actuations?
  - How much actuation is shared between the winch and rotor actuations? If the winch actuation can counter-act gravity of the SAM, wouldn't it be a simpler solution to attach the KUKA arm directly on the (actuated and dexterous-to-certain-extent) booms (with no cables)? Is the SAM also capable of generating a side-way manipulation operation (e.g., taking something from a narrow hole or window)?
  - It appears that the condition for the cable vibration suppression control is rather favorable (e.g., actuator-sensing collocated?) and it would be nicer to make it more explicit what is a novel and significant challenge of this vibration control (other than using just one IMU).
  - It would be a bit better if empirical justification is also provided on the 2 rigid-link modeling of the cable. How also did you set the inertial of these cable segments, which I guess would be fairly small? Doesn't it cause any problem of singular inertia metric or could you just eliminate them during the process of dynamics reduction?
  - The importance of frequency separation for the feedback control is well-known and it might be better to mention this to contextuate the presented framework to this concept. It would also be more convincing if some empirical data is given for this frequency separation along with the explanation on how to choose the LPF coefficients (given the signal frequency spectrum).
  - Stability is claimed by using the argument of passivity, which however can be compromised by the phase-lag of LPF, and it would be nicer if some explanation or justification is provided on the adequacy of this passivity argument with the LPF.
  - Stability of LQR is typically coming from their controllability or observability of the output mapping, and it is not so clear if this LQR solution should possess always the same structure as the passivity-based damping control. What are the stability criteria of ofLQR and how are they related to the passivity-based stability argument?
  - The symbols of body-frame angular velocity and wrench look rather similar and it might be better to use different symbol for the wrench.

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*