ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

# SUPERVISOR'S OPINION OF FINAL THESIS

## I. IDENTIFICATION DATA

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|---|---|
| **Thesis name:** | **Predictive Control of an Unmanned Aerial Vehicle with a Time-Variable Mass** |
| **Author's name:** | **Diego A. Saikin** |
| **Type of thesis :** | master |
| **Faculty/Institute:** | Faculty of Electrical Engineering (FEE) |
| **Department:** | Department of Control Engineering |
| **Thesis supervisor:** | Dr. Martin Saska |
| **Supervisor's department:** | Department of Cybernetics |

## II. EVALUATION OF INDIVIDUAL CRITERIA

**Assignment** — **challenging**

*Evaluation of thesis difficulty of assignment.*

The thesis content is challenging in sense of a required new design of motion planning approach with changing mass, understanding of UAV stabilization and control in ROS, and demanding experimental verification.

**Satisfaction of assignment** — **fulfilled**

*Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.*

The assignment has been satisfied. The motion planning problem was solved and works properly as was numerically verified. During working on the thesis, it was decided with my full agreement to focus on more complex motion planning methods and experimental verification with real platform, which was not required originally, rather than solve the problem in a model predictive control fashion as was originally requested. Results with such impressive experimental evaluation are more valuable with respect of planned robotic publication.

**Activity and independence when creating final thesis** — **B - very good.**

*Assess that student had positive approach, time limits were met, conception was regularly consulted and was well prepared for consultations. Assess student's ability to work independently.*

Student was very active and regularly consulted the approach design. He creatively proposed new research ways. Sometimes, he could work more independently and try to find solutions of problems in literature before requiring help from colleagues and faculty members, but the selected approach was correct and achieved results are valuable.

**Technical level** — **A - excellent.**

*Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.*

Technical level is high and the achieved results go beyond the state-of-the-art in UAV motion planning. The content of the thesis promises to be a good journal publication, which will be compiled in following months.

**Formal and language level, scope of thesis** — **B - very good.**

*Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.*

The thesis is well written and the text is understandable. I could read the thesis in multiple iterations and my comments were included. In the final version, I have found only a minority of typos and small grammar errors. Usage of formal notation is sometimes not standard, but it does not influence well understandability of thesis content in my opinion.

**Selection of sources, citation correctness** — **A - excellent.**

*Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.*

The literature review was compiled carefully and includes a large number of relevant sources. Citations are used correctly.

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# SUPERVISOR'S OPINION OF FINAL THESIS

**Additional commentary and evaluation**
*Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.*
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## III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

*Summarize thesis aspects that swayed your final evaluation.*
Student faithfully solved the given problem and the achieved results are valuable and exceeding the state-of-the-art in UAV motion planning. The thesis assignment was fulfilled with some modifications that we compounded together. The aim of the modifications was to maximize output of the thesis and to be able to achieve a valuable journal publication with the obtained results. Since I have to evaluate mainly the results and student's approach to goals fulfilment, I evaluate handed thesis with classification grade **A - excellent.**

Date: **13.6.2018**

Signature:

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# REVIEWER'S OPINION OF FINAL THESIS

## I. IDENTIFICATION DATA

| | |
|---|---|
| **Thesis name:** | **Predictive control of an unmanned aerial vehicle with a time-variable mass** |
| **Author's name:** | **Diego Alejandro Saikin** |
| **Type of thesis :** | master |
| **Faculty/Institute:** | Faculty of Electrical Engineering (FEE) |
| **Department:** | Department of Control Engineering |
| **Thesis reviewer:** | Ing. Martin Gurtner |
| **Reviewer's department:** | Department of Control Engineering |

## II. EVALUATION OF INDIVIDUAL CRITERIA

**Assignment** — **challenging**

*Evaluation of thesis difficulty of assignment.*

The thesis deals with designing and tracking a trajectory for a quadcopter with time-varying mass. The trajectory should be such that the quadcopter starts with a specific load attached, follows a trajectory which gets it to a state from which it can recover only if the load is detached. Furthermore, this task should be solved in a receding control horizon fashion by a model predictive controller (MPC). This definitely poses an interesting control problem.

**Satisfaction of assignment** — **fulfilled with major objections**

*Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.*

Unfortunately, I can see a few deviations from the original assignment in the thesis. First of all, the trajectory is planned offline and tracked by a controller which is barely mentioned in the thesis and which is definitely not an MPC (as it was required in the assignment). Since MPC is mentioned explicitly in the assignment, it should have been either tested (at least) in simulations or some arguments why it is impossible to use an MPC-like controller in this scenario should be provided. Furthermore, there is a requirement on comparing the approach where the change in mass is considered to an approach where the mass is considered constant. This part is missing as well. Although, I must mention that the proposed controller was tested on a real hardware, which, in contrast, was not required.

**Method of conception** — **correct**

*Assess that student has chosen correct approach or solution methods.*

My main objection is that the way the author proceeded is not well argued and documented. For instance, the goal is to design a trajectory for a hybrid model, a model consisting of several models which are switched depending on some events. The way the author approached this problem—multiple shooting + fixed-length stages + variable sampling time for each stage—is quite natural and apparently works. Nevertheless, a research of applicable methods should have been conducted and reported. This way, it looks like the author randomly chose a method which, luckily for the author, worked.

**Technical level** — **C - good.**

*Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.*

The comment from the previous section applies here as well. It is not clear why the author proceeded the way he did.

**Formal and language level, scope of thesis** — **C - good.**

*Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.*

The author has a very good command of English. The thesis is rather readable. Nevertheless, I have some formal objections. The math formulae are not properly set. The author denotes multiplication by '*' (equation (3)). Function names and text in equations should be set in an upright font not in italics (equations (3) and (19)). Subscripts with text should be set in an upright font as well (i.e. $m_{\mathrm{UAV}}$ not $m_{UAV}$). Some figures are enormously large and some are not properly labeled; some axes lack physical units (e.g. figure 7), some does not have any label at all (e.g. figure 5). Symbol $\nabla$ usually denotes a differential operator, not a vector as such, hence $\nabla_{terrain}$ is a peculiar way of denoting a vector. Table 2 does not fit to the page (at least, in the printed version of the thesis).

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# REVIEWER'S OPINION OF FINAL THESIS

| **Selection of sources, citation correctness** | **C - good.** |
|---|---|
| *Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.* | |
| I have already made the point, the author did not sufficiently work with available literature. Nevertheless, with the exception of software framework CasADi, what is used is also properly cited. | |

| **Additional commentary and evaluation** |
|---|
| *Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.* |
| - |

## III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

My main objection mentioned in almost all sections above is that the author did not argue well enough why he proceeded the way he did, why he chose the tools he used. Furthermore, the assignment is fulfilled only partly. Also, the visual aspect of the thesis is rather poor. Nevertheless, I must also take into account and emphasize that the author verified functionality of the proposed approach in field tests.

Therefore, I evaluate handed thesis with classification grade **C - good.**

Questions:

1. Why did you use discs as the load to be released? You modelled the load as a mass point and thus one would expect using a spherical object instead of a disc.
2. Why did you consider individual components of the heading vector as decision variables? This way, you have more decision variables and you have to constrain the norm of the heading vector to one. Instead, you could model the heading vector as $[\cos(\psi), \sin(\psi)]^T$ and use $\psi$ as the decision variable.
3. Does the trajectory tracking controller take into account that the load was released hence the mass of the quadcopter changed?
4. Warm starting (or hot starting) is mentioned at several places in the thesis. How do you choose or get the initial values of the decision vector when warm starting is used?

Date: **13.6.2018** Signature: