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Review of doctoral thesis
Modern Flight Control System Design and Evaluation
(Candidate: Ing. Jan Vlk)

1. Aims and scope of the thesis

The dissertation presents the process of designing and evaluating the properties of an automatic flight control system for a Light Sport Aircraft (LSA). The developed system enables automatic stabilization of flight parameters (indicated airspeed, altitude, and track). The Author additionally demonstrates the system's capabilities in navigation tasks based on the entered way points and the system's ability to perform an automatic landing approach. The demonstrated properties of the control system developed by the Candidate indicate the potential possibilities of using it to control larger unmanned objects in the future (after additional development of algorithms enabling automatic take-off, touchdown and roll-out of the airplane). The subject of the work suggests that it is very general. After carefully reading its content, however, it turns out that the issues raised in it have been resolved at a very detailed level. At the outset, the Author limits the scope of his considerations: „*This thesis introduces the reader to a Model Based Design (MBD) approach in the Flight Control System (FCS) development, harmonized with the state-of-the-art standards, best practices and regulatory requirements*”. This is a very important sentence, because the declared method of solving the problem forces the development of the most accurate model of the airplane dynamics and effective aircraft dynamics (taking into account also the control system components: sensors, regulators and actuators). The theoretical models, presented in detail in chapter 2 (6DoF nonlinear model) and chapter 3 (simulation model), were then supplemented with estimated parameter values (this process is presented in detail in chapter 4). The plant model prepared in this way was used next for the synthesis of the control laws, taking into account robust and adaptive methods (chapter 5). Chapter 6 is a presentation of the algorithms implementation into the real system. This chapter is very short, but it contains a confirmation as to the practical skills and abilities of the Candidate, which I rate very highly. The evaluation of the properties of the developed control system was carried out with details in chapter 8. The research tasks set at the beginning of the thesis have been fully completed.

2. Originality and contribution to the area of Computer Science and Engineering

Development of a high fidelity 6DoF nonlinear simulation model of an experimental LSA airplane, refined with estimated aerodynamic coefficients originating from an estimation process on measured data, is a significant contribution from the Candidate. This task is multidisciplinary, although the Author focused on the methods, which are specific to Computer Science and Engineering. Similarly, interdisciplinary tasks were related to three-phase evaluation of the designed FCS. In this process, the Candidate focuses on robustness and stability evaluation as well as on time-domain evaluation in the simulation, and next in a real flight environment. The implementation of the developed FCS in the simulation environment dedicated to the LSA class airplane is a significant contribution to the Computer Science and Engineering discipline. The FCS design based on the robust LQR control strategy, with its implementation tailored specifically for an LSA as well as the Model

Reference Adaptive Control (MRAC) based adaptive augmentation of a linear FCS evaluated in computer simulations, are original and valuable achievements of the Candidate. This work shows how important the role of Computer Sciences and Engineering is in the development and research of contemporary flight control systems.

3. Methods and results

The methods used in the study were selected correctly. The results of simulations were verified on the experimental Sport-Star airplane. Such an experimental verification, which is rarely performed by PhD students, is an unquestionable asset of the reviewed thesis. The achieved precision of FCS is very good. For example, flight parameters deviations shown in Fig. 7.29-7.36 are generally in the range of SAE requirements. On Fig. 7.31 and 7.35, we can see the limits being exceed, but this is beyond the steady level flight. Technically, the presentation of these limits in charts could have been limited to the time range of the analyzed sections. Is the SAE limit of a_z shown correctly in figure 7.35 (should it not be 0.5 g)?

Issue for discussion - the proposed linear model of the actuator (second order inertial system) is very popular in the literature, but in my opinion, it can be too simple in some cases. The rate limit (together with actuator saturation, which is fully discussed in the thesis) is a very important physical feature of an electro-mechanical actuator. Has the Author considered the linearization of actuator models for specific excitation amplitudes due to rate limits? Were the measurements of the maximum operating speed of the actuators carried out in practice? What is the maximum load of the actuator and how does it compare to the hinge moments?

4. Dissemination of the thesis results and research erudition of the Candidate

The attached list of seven publications includes works that are thematically very closely related to the thesis submitted for evaluation. I state with full conviction that the core of the doctoral thesis has been published at an appropriate level. Moreover, due to presentations at prestigious conferences, the Candidate is known in the scientific world. These publications prove the Candidate's competences in teamwork also. Most importantly, the reviewed work is a positive contribution to the present state of knowledge on flight control systems, especially for the LSA class. Its results are practical and can be commercialized. The Author's publications are noticeable in scientific databases (Scopus: 7 documents, 6 citations, h-index 2; Web of Science: 6 documents)

5. Conclusion

The topic of dissertation is appropriate to the area of Computer Science and Engineering. The thesis is up-to-date from the viewpoint of the present level of knowledge. Reviewed work is original and it means a contribution to the area of Computer Science and Engineering. The core of the doctoral thesis has been published at an appropriate level and the Candidate is a person with outstanding research erudition.

In my opinion, the value of the reviewed work is higher than generally expected from PhD theses. **The doctoral thesis of the Ing. Jan Vlk fully meets the requirements of the proceedings leading to PhD title conferment.** I grade the thesis as passed with high distinction.

Place, date

Signature