

22.7.
H. Jozusik

**A Review of the PhD thesis of Ondřej Špinka entitled
“RAMA- a Low-Cost Modular Control System for Unmanned Aerial Vehicle”**

The thesis presents the results of research that Ondřej Špinka has conducted in a very attractive, actual and complex area: control systems for unmanned aerial vehicles.

The challenge of this research consists in the necessity to perform the research concurrently in several particular fields. The thesis is a case-study which sucks the fundamental knowledge from the field of flight mechanics and mathematical modeling (of the rotorcraft) and performs a research in the field of hardware architecture, flight control, and software architecture and control system safety. The output of the research is not only a design and its description contained in the submitted thesis but also the implementation/construction of the rotorcraft including developed control system.

The achievement of presented results required fulfillment of extensive experiments and testing to ensure required functionality, safety and reliability of the developed rotorcraft model. The functionality of the model is evidenced by the attached DVD documentation. I had also the occasion to observe a live demonstration of the rotorcraft at Třešť in September 2009 which showed an excellent functionality of the model as documented on DVD.

Submitted thesis presents the achieved results in 8 chapters, among which substantial material is covered in chapters

- 2 Flight Mechanics and Mathematical Modeling of a Rotorcraft,
- 3 Control System Hardware Architecture,
- 4 Control Algorithms,
- 5 Software Architecture,
- 6 Control System Safety and
- 7 Experiments and Testing.

In my opinion the relevant contributions of the thesis are less ore more distributed within the chapters 3 to 7.

In chapter 2 the contribution is original hardware architecture of the control system. The genuineness of the chapter 3 relies on structuring of overall control into five layer control scheme, the selecting appropriate control algorithms for them and extensive testing and tuning to provide conveniently functioning set of algorithms. From five designed layers however only two lowermost have been implemented. Does it mean that by implementation of the rest of layers the new “higher” functionality could be implemented in the future? It would be therefore valuable to have in the thesis some explicit list of functions which developers are intended to realize and thus improve overall functionality and usability of the system. Nevertheless I am convinced that the implementation of this part required huge amount of experimenting and testing to be conducted to the successful end.

In my opinion excellent contribution is contained in chapters 5 and 6. The software architecture designed and implemented for RAMA consists of four separately operating subsystems communicating solely via the Vehicle Bus. Lot of work has been dedicated to proper design of the software structure consisting of concurrently working threads both in bus environment and in two parts working under Linux OS and also to finding the synchronization algorithms for them.

The chapter 6 contains a description of the various safety mechanisms incorporated in the RAMA UAV control system. These represent also a contribution of the thesis due to the specific structure of the overall control systems which is mirroring in the set of designed safety mechanisms. Also a practical functioning of the control system safety is presented.

Very valuable contributions of the thesis represent general testing methodology called Flight Readiness Test which was developed for RAMA system.


The interesting issue of the application is the sensors used in RAMA model. Here I have some questions:

1. The three-axis magnetometer is used however there is not anywhere any mention about hard iron distortion eventually soft iron distortion which could be source of considerable error, even more then 10 deg. Does it mean that the used sensor has built in compensation algorithms?
2. The transformation algorithm from magnetic north to geographical north is not described in the thesis. Since it is important for applications using GPS (uses geographical north) does it mean that this algorithm will be included in a future system where uppermost control layers (especially trajectory Tracking Layer) will be realized?
3. There is no mention about gyroscope drift. Can be neglected in RAMA application?

To summarize the review I would like to explicitly answer the review questionnaire:

- a. The subject of the thesis is topical
- b. The goals, which were set in the beginning, were completely fulfilled, even exceeded. There are several contributions which were not mentioned at the start explicitly but they were achieved and thus can be considered as "secondary" contributions of the thesis
- c. The methods of elaboration are adequate and comparable with methods used in of other projects of a similar kind (e.g. ¹)
- d. The thesis enthrones the actual and demanding theme, the presented results are excellent. The main contributions are discussed in the text above.
- e. The results of the thesis can be extensively applied in many everyday's applications which arise recently, e.g., emergency services, aerial photography, movie making industry, agriculture or traffic observations. The rotorcraft model can be used preferably in a rather hazardous environment, where the deployment of a manned vehicle would prove too dangerous. Also flexible maneuvering ability and ability to hover is something which could not be achieved with manned vehicles. The RAMA project was and is developed as open project and as such it creates excellent opportunity to further scientific continuation and development
- f. The thesis fulfills the conditions of single/independent scientific work and contains original results which have been published by the author of the thesis. The list of author's publications at thesis pages 121,122 documents his qualification and competence for scientific work.

All that is why **I recommend the thesis to be accepted for a defense** and upon its successful completion to assign Ondřej Špinka by the PhD degree.



Doc. RNDr. Jindřich Cernohorský, CSc.

VSB – Technical University of Ostrava
Department of Measurement and Control

Ostrava, April 20, 2010

¹ Kaegi- Trachesel, T., Gutknecht, J.: Minos-The design and implementation of an Embedded real-time operating system with a perspective of fault tolerance or Binotto, A.P.D et al.: Real-time Task Reconfiguration Support Applied to an UAV-based Surveillance System, both in *In Proceedings of the International Multiconference on Computer Science and Information Technology*, Wisla, Poland, 2008, ISBN 978-83-60810-14-9, ISSN 1896-7094