

Review of Doctoral Thesis

Author: Václav Navrátil

Title: Positioning and Data Fusion Algorithms for Radionavigation Systems

Reviewer: Petr Pánek, Dicom, s.r.o., Thákurova 4, Praha 6

The submitted doctoral thesis deals with the problem of positioning based on the fusion of data obtained from various navigation systems. The aim is to ensure reliable and accurate positioning even in difficult conditions where the reception of radio navigation signals is limited or impossible.

The theme of the thesis is topical, especially in the context of current rapid development of Global Navigation Satellite Systems, new in-door radio navigation methods like Ultra-Wide Band positioning, and MEMS-based inertial navigation units. I believe that the achieved results can quickly find use in practical applications.

The thesis consists of 5 chapters and 4 extensive appendices. It has a total of 230 pages. Chapters 2 and 3 contain a detailed description of various radio positioning techniques and inertial navigation. Special attention is paid to the characteristics of measurement errors with regard to the considered fusion of measured data. Chapter 4 deals with solution procedures for nonlinear positioning problems and fusion of the positioning data. The author focused mainly on methods of data fusion based on Kalman filtering including new approaches to the Kalman filter implementation and to the introduction of constraints. Other methods of fusion of measured data are mentioned only briefly. While the main text of the thesis provides the theoretical context of the author's work, the appendices present utilization of the particular principles in specific applications. The bibliography contains 168 items. The thesis fulfils the formal requests on a good level.

The thesis is not deeply focused on the only particular area but on several problems that the author solved in connection with the design of practical applications on which he worked. The used methods are up-to-date and suitable for solving these problems.

I see the main contribution of the thesis in new approaches to the application of generally known methods. The author clearly knows the necessary theoretical apparatus and proved that he can use it creatively. The original results can be found especially in appendices of the thesis which are based on his papers published in journals or presented at international conferences. An example is design, implementation and experimental verification of the soft-constrained error-state Kalman filter for an integrated positioning system described in appendix D. It has been experimentally verified that the designed approach has led to significant improvements of the positioning accuracy, particularly in canopied areas.

There are several minor errors or inaccuracies in the thesis, e.g. result of the two-way ranging in eq. (2.25) should be equal to average of partial measurement results, not the difference; missing 2π in eq. (2.26) and (2.36); VLF system OMEGA did not start its operation in 1982, but some 10 years earlier.

I have the following questions for the author:

1. The Kalman filter described in appendix D performs the fusion of position data measured by GNSS and UWB units with support of IMU. Alternatively, measured ranges, pseudo-ranges, or carrier phase measurement data could enter the algorithm. What advantages and disadvantages would such a solution have?

2. One of the current challenges in the field of positioning is indoor navigation. How could positioning data fusion be used in this area?

The objectives of the thesis have been fulfilled. The author proved his ability to perform research work and to achieve original scientific results. I recommend the thesis for presentation with the aim of receiving the degree of Ph.D.



Prague, 10 September 2019

Ing. Petr Pánek, CSc.