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The Review of Ph.D. Thesis "Detection and Estimation of Human Movement using Inertial Sensors: Applications in Neurology" by
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Reviewer: Prof. Ing. Miroslav Šimandl, CSc.

Significance for Automatic Control and Robotics. The development of sensors (e.g. accelerometers, rate gyroscopes and magnetometers) fabricated as microelectromechanical systems (MEMS), makes it possible to apply estimation and optimization methods in new areas such as neurology. The sensors generate data that are processed and evaluated by suitable algorithms known in automatic control. In neurology, the results of estimation or optimization are important for human motion monitoring and assessment, quantification of tremor and so on. Therefore, the topic of the thesis is relevant.

Aim. The thesis attempts to achieve the following aim: Develop new and improve existing methods used in human motion assessment by inertial sensors for neurology application area.

The considered aim seems reasonable because the joint usage of the new measurement devices and the current theoretical approaches enables to obtain results of a higher quality.

Contents of the thesis. The text comprises of eight chapters and two appendices. It is well structured and in accord with the aim of the thesis.

The starting point, Chapter 1, is a brief introduction and motivation. Chapter 2 introduces the inertial sensors, their properties and physical principles. The next chapter presents a brief survey of methods of human motion assessment based on inertial sensors. Chapter 4 deals with accelerometer calibration. Besides the standard methods, a new method is introduced and compared with the standard ones. Tremor quantification approaches are presented in Chapter 5. Contrary to standard approaches, the author proposed a new approach based on decomposition of the measured acceleration into the gravitational artefact and the motion acceleration. In Chapter 6, the stress is laid on mathematical modelling of the inertial measurement unit rotation and mutual orientation of two sensors for attitude measurement. The models are important tools for a design of estimation algorithms of the centre of the rotation and a relative orientation of two sensors. Chapter 7 presents attitude estimation during tremulous motion using results achieved in previous chapters. Finally, summary of thesis results and suggestions for future work are given in Chapter 8.

Technical correctness and quality of presentation. The topic requires deep knowledge of modern sensors, mathematical modelling, estimation methods and a relation to some neurological disorders. The structure of the manuscripts and achieved results confirm that the author has the necessary knowledge and has an ability to do research. A positive aspect of the manuscript is also a thorough description of the state-of-the-art of the individual areas.

On the other hand the weak points of the thesis are as follows:

- The mathematical models are not used for generating the data to perform optimization or estimation on data with known properties. Only real data are used and thus, the estimated quantities cannot be compared with true values and the decision about the quality of estimation is questionable.
- The proposed methods are often described very briefly, although they are presented as the main contribution of the thesis, e.g. method for accelerometer calibration in Chapter 4, page 27.
- Justification of the choice of methods is not consistent. For example, in Chapter 5 the UKF is recommended as a better filter compared to the EKF but in Chapter 6 the EKF is used without any discussion. Chapter 4 introduces two procedures for detection of quasi-static states, but later on (e.g. in Section 5.2.3) other approaches are used.
- The application of the UKF in Chapter 5 is not described, no algorithm is presented. Moreover, in Fig. 5.2, the UKF is used for data fusion (the term "fusion" is used also in the text), but the UKF is a tool for filtering and it is not obvious what the author meant.
- In Chapter 6 (application of the EKF), a final algorithm, is not introduced.
- The author prefers smoothers over filters for estimation of unknown quantities. It would be interesting to know whether the quality of estimates is higher.

Besides these weak points the text also contains the following minor technical inconsistencies and typographical errors:

- The whole thesis – The references to figures, tables, chapters, and sections should begin with a capital letter (e.g. The results are summarized in Table 5).
- Page 8, the first sentence in Section 2.2.3 – Number 5 is a typo.
- Page 9, Section 2.3.1 – "Bot the values change ..." -> "Both the values change ..."
- Page 9, Section 2.3.1 – How it is ensured that the Earth-reference frame for the magnetometer is oriented in the same way as the Earth-reference frame for the inertial sensors?
- Page 13, the fifth row from the top – "The information was get from ..." -> "The information was got from ..."
- Page 26, Section 4.3.3 – The presentation of the method is not too clear. There is also a sentence after the definition of Y that seems to be unfinished.
- Page 41, Section 5.2.3 – What is the assumption on the initial condition of the model.
- Page 45, the last sentence in Section 5.2.3 – The end of the sentence is not clear.
- Page 55, Section 5.4.3 – The meaning of the abbreviation UPDRS is not explained.
- Page 59, Section 6.1.2 – The meaning of \hat{b} is not explained.
- Page 61, Section 6.1.4 – The order of S_k and R_k is probably switched after (6.4).
- Page 85, the last sentence of the second paragraph of Section 7.4.1.4 – "...the first second of ..." -> "..., the first half of ..."

Acquirement of the aim and new results. The aim is acquired in Chapters 4-7, where several original results were presented. The main results are the following:

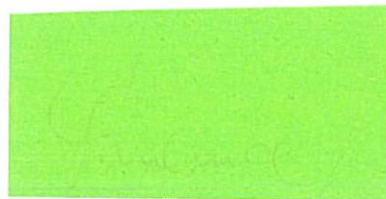
- An application of the EKF or the IKS to estimate the centre of rotation during tremulous motion, Chapter 6
- A new method to find the relative orientation of two attitude measurement systems, Chapter 6.
- An improvement of attitude estimation quality, Chapter 7
- A design of new procedure of the accelerometer calibration, Chapter 4.

I believe that the thesis results are interesting both for automatic control and neurology communities.

Other comments. The author published several papers related to the thesis topic, 3 journal papers, 4 papers presented at international conferences.

Conclusion. The text under review contains very good state-of-the-art of the investigated topics and introduces several new results in neurophysiology by applying methods from automatic control. It is my understanding that this manuscript fulfills the conditions laid on Ph.D thesis. I recommend the Ph.D thesis to the defense.

In Pilsen, May 4, 2012



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The first part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, which are based on the principle of the uncertainty of the position and momentum of the particles.

In the second part of the paper, the author discusses the results of the experiments on the structure of the atom. It is shown that the results of the experiments are in good agreement with the predictions of the theory of the structure of the atom.

The third part of the paper is devoted to a discussion of the applications of the theory of the structure of the atom. It is shown that the theory of the structure of the atom has many important applications in the field of physics and chemistry.

In the fourth part of the paper, the author discusses the future prospects of the theory of the structure of the atom. It is shown that the theory of the structure of the atom is still a subject of active research and that many new results are expected in the future.

The fifth part of the paper is devoted to a discussion of the conclusions of the paper. It is shown that the theory of the structure of the atom is a very important part of the theory of the structure of matter and that it has many important applications in the field of physics and chemistry.

In the sixth part of the paper, the author discusses the bibliography of the paper. It is shown that the paper is based on the results of many experiments and theoretical calculations.

The seventh part of the paper is devoted to a discussion of the acknowledgments of the author. It is shown that the author is grateful to many people for their help and support during the preparation of the paper.

In the eighth part of the paper, the author discusses the references of the paper. It is shown that the paper is based on the results of many experiments and theoretical calculations.

The ninth part of the paper is devoted to a discussion of the conclusions of the paper. It is shown that the theory of the structure of the atom is a very important part of the theory of the structure of matter and that it has many important applications in the field of physics and chemistry.