

REVIEW

about the Ph.D. thesis for acquisition of the scientific degree “doctor” in the professional field 5.2 Electrical engineering, Electronics and Automation, scientific specialty Automated system for information processing and management.

Author of the Ph.D. thesis: Milena Filipova Groueva

Topic of the Ph.D. thesis: Group control of robotized means for transport of loads

Reviewer: prof. D.Sc. eng. Todor Atanasov Stoilov , Institute of information and communication technologies – Bulgarian Academy of Sciences, Sofia, Acad.G.Bontchev str., BL.2

General notes

The Ph.D. thesis has 154 pages and it contains 3 chapters. In the conclusions of the thesis the authors' contributions are presented. The referee list contains 101 positions. The authors' publications are given with a list with 9 titles.

1. Actuality of the problems in the Ph.D. thesis

The added value of the researches in the thesis concerns definition of analytical and program models for the motion of robotized means of transportation. The goal is to control their motion by means to implement group control, following a leader by set of slave robotic transportation units. In the first part of the Ph.D. thesis it has been performed numerical experiments by application of formal analytical models of the robot motion. The target of the control is to minimize the deviation between the locations of the leader and the following robots. In the second part of the Ph.D. thesis it has been performed program simulations in a special programming environment Webots for the group motion of platoon of robots. Assessments and comparisons about the accuracy of deviations between the leader motion and follower one are made. Hence the Ph.D. thesis makes quantification of the accuracy between the group motion of follower set of robots and a leader one.

I assess positively the research domain of the Ph.D. thesis. My personal opinion is that this work is useful, because it addresses practical case of technological system with a set of operating robots, which perform transportation services, which case is widely used in many production activities in practice.

The relevance and significance of development such topic is easy understandable because it addresses the group control of transportation robots, which has wide practical application.

I find that the importance and significance of the Ph.D. researchers are evident, which gives positive attestation for the qualification of the Ph.D. student.

2. Degree of knowledge acquired by the student

The Ph.D. thesis presents profound analysis about the types of existing robotized means, their place and utilization in the current practice. It is given classifications about the technological structure of the robots, their mean of operation, domains of applications.

In chapter 1 is presented an analysis and classification of the mobile robots. This chapter targets the topic of control case for a group of robots, which is important research and practical domain, which has wide application importance.

In chapter 2 it has been given the set of formal relations, which model in analytical way the motion of a robot. It has been given the set of differential equations, which origin from the domain of mechatronics concerning motion, rotation, position changes. These formal relations are modified for derivation of analytical description of group robot motion particularly for the policy "following a leader. In the Ph.D. thesis it has been presented in graphical forms the numerical assessments about the accuracy of the followers towards the leader motion. This chapter contains formal derivation of motion dynamics of a group of robots for the implementation of procedure to follow the leader.

In chapter 3 a program modeling of the mobile robot behavior is performed. It has been used a special program environment, which simulate the robot motion according to predefined parameters and targets to the robots. This program environment allows to be performed a lot of experiments without the usage of real physical robot devices. This chapter contains an extensive explanation about the simulation environment and its functionalities.

In chapter 4 it has been made an attempt for physical control of a real engine of robot. In considerable part of this chapter it has been presented the constructive components of a transportation robot, manners of wireless communications. The experiments, which have been provide in main part repeat these one, given in chapter 3 in the Webots environment.

The Ph.D. thesis uses 101 reference and information sources, by means to make an extended overview about the practical applications of the mobile robots in different domains of the current practice. The Ph. D. students made efforts to follow practical solutions, which relate to the group control of mobile robots.

3. Correspondence between the chosen research methodology and the goals and problems targeted in the thesis

The goal of the Ph.D. thesis is defined in the end of chapter 1 as "...to investigate the types of mobile group control and to offer innovative approaches for group control...." This goal is decomposed to 6 problems, concerning development of a system for group control of robots and to test their functionalities in different cases.

My comment is that the Ph.D. thesis states development of a system, but the content part of it concerns analytical and programming simulations in "leader-follower" policy of group of robots.

I find that the topic of the Ph.D. research has considerable internal complexity, resulting from the real technical system of robots. My assessment is that this topic has scientific and applied nature. The Ph.D. thesis makes analysis of a complex object,

which has to coordinate in real time the transport motion of mechanical robots for transportation services.

The Ph.D. student demonstrates that he has allocated a lot of efforts and did *hard work to be acquainted with formal analytical models for the dynamics of the robot motion, numerically to evaluate accuracies and errors between the leader and followers positions. These numerical experiments in the Ph.D. thesis have been checked also by program simulation with special software environment.*

4. Characteristics of the Ph.D. thesis

Following the defined tasks in the PH.D. thesis, in chapter 1 was made analysis about the existing solutions for the domain of mechatronics and the technical representatives in this domain as robots. This analysis was oriented toward the topics of structure and manner of motion of robots, application areas and potential benefits from them.

In chapter 2 it has been derived the analytical description of the motion of unique robot. This model then has been complicated by means to define the set of analytical relations, which formalize the motion of group of robots and the implementation of the motion policy "leader-followers". In this chapter it has been solved analytical relations for the estimation of the errors and accuracies for following the leader motion.

In chapter 3 it has been provided program simulations for the policy of following the leader by a group of robots. It has been used a special software environment, which can test different modes of group control.

In chapter 4 it has been made an attempt for presentation of the technological structure of a transportation robot. The experiments, which are made have the same character and replicate these ones, given in chapter 3.

The Ph.D. thesis contains results about the accuracy of the implementation of the group control.

The referee finds the presented results are useful and give appropriate illustration for the achieved professional qualification of the Ph.D. student for studying and application of control decision for the case of group robot control..

5. Scientific and practical achievements in the Ph.D. thesis

In the Ph.D. thesis it has been defined and analytical model and procedure for control of group transportation robots for implementation of control policy "leader-followers". It has been made analytical and program simulations for the implementation of such group motion. Numerical assessments are made for the accuracy of the implementation of this control strategy.

My assessment is that the topic of the Ph.D. thesis allows achieving research and application results. It has been analyzed a complex object, which have complex formal description.

I appreciate positively the workload and the achieved qualification of the Ph.D. student, who is able to perform independently scientific researches in difficult engineering domain.

I find that the Ph.D. thesis has research and application contributions for the case of analytical and program modeling of the motion of a group of transportation robots.

My assessment is that these researches and application results are sufficient for this Ph.D. thesis. They prove that the Ph.D. student can implement independently scientific and engineering researches, to apply analytical and program tools for analysis, definition and testing control policies for complex technological systems as a system of transportation robots. It is seen from the description of the Ph.D. thesis that the student can address and implement his own solutions for the domain of group robot control.

Making this review I have a belief that all results in the thesis are achieved personally from the Ph.D. student.

6. Assessment of the publications, made for the Ph.D. research

The reviewer finds that the presented publications correspond to the topic and the content of the Ph.D. thesis. It has been made 9 publications for the period 2011-2018. The works have been published on conferences in our country, in foreign and national edited journals.

The reviewer accepts that the presented publications satisfy the legislative and internal requirements of the Institute of information and communication technologies – Bulgarian Academy of Science for acquiring the educational and research degree “doctor”.

7. Significance of the research and application achievements in the Ph.D. thesis

The Ph.D. student Milena Groueva demonstrates abilities to use methods and tools for analysis and design of control algorithms for specialized and complex system with transportation robots. It has been demonstrated professional knowledge of the technical devices and the manner of their usage for the implementation of system of transportation robots.

It is evident the intention of the Ph.D. student to develop and to prove better results in the control of group of transportation robots. .

The reviewer finds that the works in the Ph.D. thesis are useful.

In the presented documents there are not protocols for dividing the achievements in the publications between the authors.

8. Few assessments, recommendations and remarks

My personal assessment for the presented Ph.D. thesis is positive. One can easily identify that the Ph.D. student allocated many efforts to provide this research.

As recommendation the reviewer is willing to find comparisons between the numerical results in the Ph.D. thesis with analogical ones, by the application of another control laws for the management of group of robots. Comparisons can be made also for the developed different programming and simulation models. Currently the results of the Ph.D. thesis has meaning of presentation the own results from numerical and programming experiments. The lack of comparisons makes difficult for claiming the authors' contributions and useful solutions. I recommend for the future works and developments of the Ph.D. student to use always the element of comparison in his conclusions and claims.

The Ph.D. thesis is prepared carefully and the reviewer doesn't consider that he has to made remarks from formatting character. From meaningful point of view the reviewer finds that the contributions have declarative character and it misses assessment components in them.

For example the contributions are defined with the term "...is proposed.." doesn't give indication about achieved positive or beneficial result. The reviewer' suggestion is after such declaration for innovative approach to be demonstrated the benefit of such innovation, what is the content of the innovation.

I recommend to my younger colleague in future to pay attention on his works to be precise and completeness of definition and presentation his research results.

These recommendations make remarks to the manner of presentation of the Ph.D. results, but they don't make doubts about their correctness.

These assessments, recommendations and remarks have meaning of sharing positive research experience between an elder colleague with his younger one.

The reviewer finds that the Ph.D. student Milena Groueva gives proves that she can make independently and by herself researches in the domain of engineering design of control policies for transportation robotic systems.

The reviewer does not make formatting remarks to the Ph.D. thesis, because the typos are responsibility of the Ph.D. student.

Conclusions

I give positive assessment for the presented research and application results in the Ph.D. thesis of Milena Filipova Groueva. My estimation is that the legislative requirements of the Law for academic growth in Bulgaria, the Regulations for its application and the specific requirements of the Institute of information and communication technologies – Bulgarian Academy of Sciences are satisfied. This give me reasons to recommend to the honorable Scientific Jury **Milena Filipova Groueva to be awarded** with the Educational scientific degree "doctor" in the professional field 5.2 Electrical engineering, Electronics and Automation, scientific specialty Automated system for information processing and management.

22.06.2020

Reviewer:

**NOT FOR
PUBLIC RELEASE**

Prof. D.Sc. eng. Todor Stoilov