REVIEW

on the Dissertation of Eng. Alexander Genchov Ranov

on the topic

"Model for routing and motion control of an autonomous combat platform"
for obtaining the educational and scientific degree "Doctor"
From

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The present review was prepared on the basis of the decision of the Scientific Council of the Institute of Defence "Prof. Dr. G. Sotiorirov". Tsvetan Lazarov" (Protocol № 95/12.01.2024) and the Order of the Director of the Institute of Defence "prof. Tzvetan Lazarov" 37/16.01.2024 for the conduct of the defense for obtaining the educational and scientific degree "Doctor" and Article 10 (1) of the Law on the Development of Academic Staff in the Republic of Bulgaria.

1. Relevance and significance of the developed scientific problem, aim and objectives of the dissertation work

Global navigation systems are playing an increasing role in human activity. At present, their application in civil and military activities is extremely high. With the help of global navigation systems, modern computer technology and communications, the quality of management and control of antonomous platforms for different purposes - land, sea and air - has increased dramatically.

In this regard, the dissertation submitted for review on the routing and motion control of an autonomous battle platform (ABP) is highly relevant. The thesis appears to be a generalized study of scientific and applied nature related to the investigation and evaluation of the capabilities of ABP using inertial navigation systems. An evaluation of the effectiveness of the proposed routing model and motion control methods for autonomous platforms has been carried out using analytical and simulation models developed for this purpose.

The development of the theoretical and experimental material in the dissertation coincides with the increasing importance of the efficiency of the means of command and control of autonomous platforms, which in the conditions of information conflict are increasingly demanded in terms of their efficiency, radioelectronic protection, electromagnetic compatibility, etc.

This defines the main objective of the dissertation, related to the study of the possibilities of creating and testing a route-ticization model and proposing appropriate methods to control the movement of ABP.
To achieve this goal, the author has solved the following tasks:

1. Development of a mathematical apparatus and algorithmic procedures for routing a ground platform without using the existing road network and avoiding visibility from an adversary observation point;
2. Synthesis of an information processing model for ABP routing;
3. Validation of the model under test software environment conditions;
4. Proposing inertial navigation methods and algorithms for autonomous platform motion control;
5. Practical application of the model in transport-warfare tasks.

The aim and objectives set by the PhD student are correctly formulated and correspond to the idea of a typical scientific and applied research, such as the present dissertation.

2. General characteristics and structure of the dissertation

The dissertation consists of an introduction, four chapters, conclusion, references and appendices with a total of 170 pages and contains 81 formulas, 50 figures and 11 tables. The reference list comprises 111 sources, of which 97 in Latin and 14 in Cyrillic. The dissertation is illustrated with color figures and graphs, which allows a good illustration and perception of the results obtained.
In Chapter 1, "A survey of current advances in theory and practice in the application of autonomous platforms", the current status and development trends of autonomous vehicles with both civil and military applications are analyzed and their advantages and disadvantages are pointed out.
Solutions in the civil sphere related to increasing transport safety, lowering financial costs, ensuring the necessary environmental effect and others are presented.
The requirements for autonomous combat platforms are justified in relation to the tasks they perform, in order to achieve battlefield advantage and make it more difficult for the enemy to counter.
Known methods of routing, navigation and control during movement of autonomous mobile systems using inertial navigation are analyzed. The

limitations in the scope of research and a summary structure of the presented work are given.

In Chapter 2, "Problems and Solutions in Routing an Autonomous Combat Platform," the possible problems and solutions in routing a combat autonomous platform are investigated and evaluated .

As a result of the conducted research, an information processing model is proposed for planning the path of an autonomous combat platform for covert movement concerning a known enemy observation point and with capabilities to overcome a certain slope in the direction of movement. A suitable mathematical apparatus is defined to represent the slope of the ground surface and to define visibility zones. For the purpose of the study, a workstation with specialized software QuantumGIS was also structured and the proposed estimation algorithms were validated using the Python and C++ programming languages.

The mathematical foundations for the localization of unmapped nearby obstacles with the application of computer vision methods using a stereo camera are discussed.

In Chapter 3, "Methods and Algorithms for Motion Control on an Autonomous Combat Platform," an analysis of the main problematic points in performing motion control procedures on a ground-based autonomous platform is conducted. A model for autonomous platform motion speed control based on inertial navigation sensor (MEMS) and with closed-loop feedback application is established. A software implementation of the Fourier transform is used to determine the characteristic of the disturbance frequencies in the motion of the ground autonomous platform, and an innovative software approach and computational procedure based on an adaptive digital filter is used to control the motion of the autonomous platform.

An original method for spatial compensation of deviations in magnetometer sensor readings is proposed, which is applicable to all design variants of autonomous platforms for which the magnetometer sensor is physically separated from the accelerometer and gyroscope sensor. The proposed method has been validated and a numerical evaluation of the improvement in the accuracy of the results in determining the azimuth of motion of the ground-based autonomous platform has been obtained.

Chapter 4, "Combat Capability Analysis for Execution of Terrain Tasks," is devoted to practical verification of the effectiveness of the proposed routing control methods for the movement of an autonomous combat platform.

An architecture for routing and movement control of an autonomous combat platform in preparation and execution of various operations is proposed. An experimental setup for conducting model studies is presented for the "navigation" and "control" architecture components.

In the experimental work, the established physical model of an autonomous platform is used.
An analysis of the energy characteristics of the autonomous combat platform has been performed by comparing the known loading characteristic of the energy source used in the physical model with the experimentally obtained external velocity characteristic at different driving modes. On the basis of the investigations, a methodology for determining the feasibility of a given route is proposed.
The dissertation ends with a conclusion in which the scientific and applied contributions, literature and appendices are presented. Emphasis is placed on the study of the possibilities of using ground-based autonomous systems in the military domain.
The approach chosen by the PhD student ensures the achievement of the goal and objectives set for the scientific work.

3. Characteristics of the scientific and applied contributions in the dissertation. Reliability of the material

In reviewing the dissertation, it can be concluded that the doctoral student has a thorough knowledge of the state of the problem and has creatively approached in its development and solution. In essence, the author has strictly adhered to the basic scheme of scientific research - description of functional dependencies between the main parameters and methods of research, modeling and verification of the adequacy of the obtained results.
The selected and accurately implemented approaches to solving the scientific problem and the possibility of its practical application characterizes the PhD student as a well-informed, creative appreciator of the level of development and achievements in the scientific field related to the routing and motion control and application of autonomous combat platforms and as a researcher is able to independently formulate and solve complex scientific problems.
The achieved results are new approaches, methods, models and further development of the existing knowledge, supplemented with experimental and factual material. The conclusions drawn correctly explain the physical picture of the phenomena studied and are logically complete, therefore the material is credible and the claimed contributions should be acknowledged.

4. Evaluation of the scientific results and contributions of the thesis

In principle, I accept the contributions of the thesis as formulated in the dissertation and the abstract, but according to the generally accepted terminology

I would summarize the scientific contributions as: proving by new means essential new aspects of existing scientific problems and theories; new schemes of research and inquiry; obtaining new and confirmatory facts.
As a result of the author's research, the capabilities of ground-based mobile autonomous platforms and their application in the military have been evaluated by synthesizing appropriate methods and models, developing algorithms and an experimental setup for the study, evaluation and control of the movement of autonomous combat platforms.
The novelty and originality of the work lies in the experimental setup created for conducting model studies and the obtained energy characteristics during the movement of a physical model of an autonomous platform, as well as the proposed methodology to determine the feasibility of a given route.
The assessment of the level of the dissertation and the author's personal contribution leads me to the conclusion that the presented dissertation meets the requirements for independent scientific research of high scientific level, as claimed in the Law on the Development of Academic Staff in the Republic of Bulgaria and the Regulations for its application.

5. Evaluation of dissertation publications and authorship

A total of 4 publications on the topic of the dissertation have been presented in scientific journals and proceedings abroad and at home - at national conferences with international participation, which is sufficient as the number of credits in the credit system adopted at the Institute of Defence. Two of the publications are joint works of the author with his scientific advisor, and the rest are independent. One publication is in a publication with impact factor.
In the published articles and reports the main points of the dissertation are revealed, which enables interested persons to get acquainted with the results.

6. Literary awareness and competence of the PhD student

The PhD student has a very good knowledge of the research problem, which is demonstrated in the work presented. The same is evidenced by the large number of sources used in the literature review, most of which are in Latin. Most of the literature sources used are from the last decade.

7. Evaluation of the abstract

The 40-page abstract adequately reflects the structure and content of the dissertation.

8. Critical remarks

The following critical remarks can be addressed to the layout of the thesis and the abstract:

1. The presented list of abbreviations adopted in the thesis is incomplete, which in some cases makes it difficult to perceive the content.
2. Fig. 3.16 is presented with two different titles, such as "Visualization of the Earth's magnetic field pattern" and "Self-diagnosis and compensation of factory detected deviations in MPU9250" .

The above criticisms, which are of a formal nature, do not detract from the merits and contributions of the submitted thesis. It is a complete work, with both scientific and applied contributions, illustrating the author's very good knowledge of the basic tools for creating a model for routing and motion control of an autonomous combat platform, as well as demonstrating the PhD student's ability for independent scientific and research work.

9. Conclusion

The positive evaluation in the analysis of the dissertation and the author's personal contribution to the achieved results gives me grounds to conclude that the presented dissertation on "Model for routing and motion control of an autonomous combat platform" complies with the requirements of the Law of the Republic of Bulgaria and the Regulations for its application for obtaining the educational and scientific degree "Doctor".

In this regard, I recommend the members of the esteemed scientific council of the Institute of Defence "Prof. Tsvetan Lazarov" to open a procedure for the defense of the dissertation of Eng. 5. Technical Sciences, 5.2. "Electrical Engineering, Electronics and Automation" in the doctoral program "Automated Systems for Information Processing and Management ".

Reviewer .....

13.02.2024 Prof. PhD, DSc, Eng. Georgi Sotirov