OPINION
for dissertation
for the acquisition of an educational and scientific degree "Doctor"

Area of higher education:	4. Natural Sciences, Mathematics and Informatics
Professional field:	4.6. Informatics and Computer Science
Doctoral program:	Information Systems (Embedded and Autonomous Systems)
Dissertation topic:	Modelling and Control of an Anthropomorphic Robot Arm
Author of the dissertation:	Lyubomira Lachezarova Miteva
Scientific supervisors:	Prof. Evgeniy Krastev, PhD Assoc. Prof. Ivan Chavdarov, PhD
Author of the opinion:	Assoc. Prof. Krasimira Minkova Ivanova, PhD Institute of Mathematics and Informatics at BAS
Based on:	Order of the Rector of SU No. РД 38-114/06.03.2023

The opinion was prepared under the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application and the Regulations for the Terms and Conditions for Acquiring Scientific Degrees and Holding Academic Positions at Sofia University "St. Kliment Ohridski".

I have been presented with the necessary documents for electronic assessment, including a dissertation (132 pages), an abstract in Bulgarian and English and publications related to the topic of the dissertation.

Lyubomira Miteva presents 6 publications, published in the proceedings at IEEE and ACM conferences or included in volumes of CEUR Workshop Proceedings, all indexed in Scopus, which significantly exceeds the required minimum of 30 points according to the PPZRASRB table.

GENERAL PRESENTATION OF THE AUTHOR OF THE DISSERTATION

Lyubomira Miteva has a master's degree in informatics, speciality "Mechatronics and Robotics" from the Faculty of Mathematics and Informatics of Sofia University "St. Kliment Ohridski". From February 2020 to February 2023, she continued his education in the same place as a full-time doctoral student in the doctoral program "Information Systems" – Embedded and Autonomous Systems; the result of this doctoral study is the presented dissertation. During her PhD,

she worked as a part-time lecturer at FMI, conducting exercises in "Introduction to Programming" and "3D Modelling and Design and Applications in Robotics".

GENERAL DESCRIPTION OF THE DISSERTATION WORK WITH THE INDICATION OF THE CONTRIBUTIONS

The aim of the dissertation is the creation of a mathematical model and prototype of a planar anthropomorphic robot with additional degrees of freedom, as well as the creation of methods for planning an optimal trajectory of movement in the presence of static or dynamic obstacles in the robot's working area. The choice of such type of robots is dictated by their increasing use in dynamic and collaborative environments, where additional degrees of freedom allow them to perform the given task regardless of the obstacles that arise.

To achieve the goal, 5 main tasks were set and performed, including the classification of existing types of solutions to the inverse kinematics problem for a planar robot with additional degrees of freedom, research and creation of algorithms for its movement, analysis and selection of appropriate components and software environment for control, prototyping the robot through 3D printing, and finally verifying the proposed hardware and software control system and the trajectory planning algorithms, through computer simulation and experiment with the designed robotic system.

In Chapter 1, the types of robots are classified according to various characteristics – drive method, kinematic scheme, and number of degrees of freedom. Kinematics modelling is described and the most popular motion planning methods are analysed. Popular software and hardware robot control system architectures, as well as various operating systems and middleware platforms, are reviewed. 3D printing techniques for robotics purposes are also discussed. The information presented in this chapter provides the general basis on which to carry out the dissertation work.

In Chapter 2, the functional requirements for the robot are defined, the focus of the research is on the number of links and joints, their physical characteristics, the need to perform the movement with minimal resistance and deviation from the trajectory, as well as the orientation in the working space and the possibility of building a model of behaviour relative to the current state. The solutions of the forward and the inverse kinematics problems are also considered here. Depending on the signs of the rotation angles of the second and third joint coordinates, the solutions of the inverse kinematics problem are divided into 4 types. It is shown in the example how the workspace of the robot is divided into different zones that can be reached by the corresponding solutions, from which it can be seen that there are trajectories in the workspace of the robot, the implementation of which requires changing the solution type of the inverse kinematics problem. In addition, the case of the presence of obstacles, which complicates the trajectory, as well as transient configurations, which can lead to deviation from the trajectory and extension of the execution time, are also considered. The contributions in this chapter – the created approach to classifying by type the solutions of the inverse kinematics problem for a planar robot with additional degrees of freedom, the analysis of its workspace in the presence of obstacles and the study of the service angle in its workspace, can be classified as applied scientific contributions.

Chapter 3 contains a description of the main elements responsible for realizing the robot's movement – calculating the positions that the robot gripper must reach, taking into account the limitations of the robot and the available obstacles in the workspace; finding the joint coordinates of the robot that satisfy these positions; sending the necessary signals to the actuators to perform the desired movement. Hardware and software control system requirements are described, and appropriate components and systems are selected to meet them. An algorithm based on graph theory has been developed for motion planning and the correct execution of a given trajectory. For this purpose, a kinematic analysis is performed to determine the number of transition situations that the robot may encounter during its movement from the current point to the goal. Since there are multiple solutions to the inverse kinematics problem for each point, the solutions are limited to cases where the solutions are equidistant from each other. This allows the construction of a weighted graph on which to find a minimum cost path for the desired trajectory. Conducted experiments of the solution-finding algorithms show the advantage of the proposed algorithm. An algorithm is proposed for pathfinding under static obstacles by creating a graph with the possible safe positions of the robot and finding a path by applying BFS. An extension of this algorithm was created for real-time dynamic obstacle avoidance in the robot workspace. The proposed algorithms represent applied scientific contributions.

Chapter 4 verifies the proposed algorithms through computer simulation using Webots simulation software and real experiments with the created prototype. The created computer experiment of the developed trajectory planning methods and the results of real experiments with a 3D printed prototype of a planar robot with additional degrees of freedom, verifying the proposed algorithms for trajectory planning in the presence of static or dynamic obstacles in the robot's workspace can be considered as applied contributions.

The conclusion summarizes the obtained results and completed tasks, as well as defines the tasks for future development.

A wide range of literary sources was used: a total of 98 references (4 of them in Bulgarian, the rest in English; 16 are references to the documentation of various systems, the rest are references to books and publications). The development of the topic over the years is sufficiently well-tracked (about 20% of the sources are from the previous century, almost as many are from the beginning of our century, more than half are from the previous decade, and almost 10% are from the last three years).

The work is original and plagiarism is not detected.

All the work of Lyubomira Miteva stands out with a systematic approach to exposition, thorough presentation of research and original ideas.

EVALUATION OF THE ABSTRACT FOR THE DISSERTATION WORK

The abstract (in Bulgarian and English) reflects the essence of the dissertation work, the main contributions, as well as the work of Lyubomira Miteva in the fulfilment of the tasks of the doctoral studies. The text is well structured.

PUBLICATIONS AND OTHER ACTIVITIES RELATED TO THE TOPIC OF THE DISSERTATION

Lyubomira Miteva presents six publications related to the topic of the dissertation. They reflect essential elements of the dissertation research. The declarations of the equality of contribution of all authors have been provided for each of the publications.

Lyubomira Miteva has an active publication activity – 20 articles indexed in Scopus; 4 of them are cited 6 times in other articles indexed by Scopus (excluding self-citations). He is actively involved in scientific research projects. He also runs a students course related to the subject.

NOTES TO THE DISSERTATION

I have no significant notes on the dissertation work.

The proposed algorithms are original, but in my opinion a little vaguely described.

CONCLUSION

The dissertation meets the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for the Implementation of this law and the relevant Regulations of SU "St. Kliment Ohridski". I give my positive assessment and propose to the respected scientific jury to award the educational and scientific degree "Doctor" to Lyubomira Lachezarova Miteva in the area of higher education 4. Natural Sciences, Mathematics and Informatics; professional field 4.6. Informatics and Computer Science.

01.05.2023 Author of the opinion:

Sofia Assoc. Prof. Krassimira Ivanova