REVIEW

on a dissertation for the acquisition of the educational and scientific degree "Doctor" in the field of higher education 5. Technical sciences, professional field 5. 2 Electrical engineering, electronics and automation.

Author: M.Eng. Vasil Georgiev Tsvetkov

Topic: Increasing the cognitive abilities of robots through optimization of their sensor system

Member of the scientific jury: Prof. PhD Eng. Pancho Tomov

1. **Relevance of the problem developed in the dissertation.**

The problem is topical. Sensor systems are the sensory organs of the robot, which allow it to collect information from its surrounding environment. These sensors can be cameras, microphones, touch sensors, proximity sensors and many others. By integrating different types of sensors, robots can capture and process data from different modalities, simulating human senses and expanding their perceptual abilities. Such a development is certainly timely, modern and useful for science and especially for practice. It also finds its place in the field of high-tech systems, functioning as a component in Cyber systems.

The problem of the state of the cognitive abilities of robots to adapt to new situations, to learn from their interactions and, accordingly, to optimize their behavior by using data from multiple sensors simultaneously, combining different modalities to form a more comprehensive understanding of their surrounding environment has been studied and analyzed. On this basis, methods and opportunities for improving their efficiency through new modern technical solutions have been clarified. From this point of view, the doctorate contains significant reserves in increasing its theoretical and practical effectiveness in terms of its scale, as well as an approach to solving specific tasks of this nature. Moreover, the problem of implementing and using new forms, approaches and methods for integration of highly automated technological systems is one step forward and in increasing their automation level.

2. **Degree of knowledge of the state of the problem and creative interpretation of literary material**

The dissertation is 122 pages long. It consists of a list of abbreviations, an introduction, four chapters, a list of references and appendices. The main text is presented on 102 pages, containing 42 figures and 8 tables. The bibliography covers 96 titles, of which 16 are in Cyrillic and 80 in Latin. The appendices are arranged on 17 pages, including 1 table and assembler program code. The achievements made so far in this area have been analyzed and the goals and objectives of the dissertation have been formulated based on analytical conclusions. In this case, the problem has been reduced and specified only to the proposal of an approach and methodology for the selection of sensors and the design of an optimal sensor-information system. Therefore, I believe that the goal of the dissertation formulated in this way fully corresponds to the development of the doctoral thesis.

As for the literary awareness of the doctoral student, it is good. Good consistency has been applied both in terms of structure and in terms of the scope of the information material in the field of sensory systems and cognitive abilities of robots.

The doctoral thesis in its form, order, sequence of presentation and essence completely exhausts the previously set condition to meet the requirements for obtaining the educational and scientific degree "doctor". My assessment is that the doctoral student knows the state of the problem well and analytically and creatively evaluates and interprets the overview-information material. He uses appropriate statements in all stages of work - from analysis to conclusions and formulations. Moreover - from this large volume of information, he has very successfully specified the problem to the selection of only the components related to the integration of the sensory-information systems of robots.

3. **Compliance of the chosen research methodology with the set goal and objectives of the dissertation work**

The research methodology is successfully chosen and suitable for this type of goal and tasks. It is suitable for such an activity, related to the use of analytical information and comparative technical analysis. It provides an answer to the set goal both with the choice of tasks to be solved, and with their complexity, scope and sequence of development. The features of modern conditions are well studied and analyzed, including the stages of practical and theoretical development of sensor technology: The main types of sensors and their role as converters of physical quantities into electrical signals that can be analyzed and processed by

the robot are considered. The generalized model of the sensor, including input and output quantities and possible disturbing factors, such as noise and parasitic influences that can deteriorate the quality of the data, is examined in detail.

On this basis and in this way, the main tasks containing the essence of the doctorate are well formulated. The theoretical and meteorological aspects of the approach to solving the problem are exhaustively clarified. There is an opportunity to search for new forms and ways to include modern solutions in this integration process. An overview of existing solutions for designing sensor systems for cognitive robots has been made, and the currently relevant sensors have been analyzed and classified. The choice of approach has been theoretically justified and the conditions and possibilities for testing and applying the approach in practice have been successfully formulated. The boundaries of the scope and the possibilities for assessing its practical applicability have been successfully determined. An attempt has also been made to assess the theoretical and practical applicability of the developed problem by testing the approach. . The assessments and evidence are successful and acceptable both in individual chapters and as an overall presentation.

4. Assessment of the nature and credibility of the material

The material on which the PhD is built is reliable, based on the modern role of sensor systems in different classes of robots: An analysis of the use of sensor systems in different types of robots such as industrial, service and medical has been carried out. . These are current problems that require continuous monitoring, analysis and solution, and which in the future, with the development and application of new, higher-tech automated control systems and work-based cyber-systems, will gain increasing importance. A section is included that focuses on metrological parameters, such as accuracy and sensitivity, which are essential for the effectiveness of sensors in robotics.

5. Contributions of the dissertation work

The contributions are of a scientifically applied and applied nature.

5. 1. Scientific and applied contributions

- Based on the research conducted in the literature review on the topic, an overview classification of the current sensors currently existing in terms of their characteristics and their applicability in various technical systems has been made
- A methodology for designing an optimal sensor system intended for cognitive robots has been proposed.

- Experimental results have been obtained in the study of optimally designed sensor modules.

5. 2. Applied contributions

- A mobile platform has been designed and implemented, suitable for use as a universal technical tool for testing the functional capabilities and technical characteristics of the developed optimal sensor systems of modules.
- Optimal sensor modules have been created such as: Sensor module for measuring temperature; Sensor module for measuring light intensity in the visible spectrum. In terms of software, the following modules have been created: initialization procedure for the selected optimal PIC microcontroller; software module controlling communication between the microcontroller and the smart sensor; module for visualization of a 7-segment display; software module for converting data packets received from the smart sensor into a format suitable for reading.
- A mobile application for Android has been developed, serving as a human-machine interface for controlling the mobile platform designed for cognitive robots.
- Based on the results obtained, during experimental studies, an assessment of parameters and states of the sensors has been made, which is part of the process of designing an optimal sensor system for cognitive robots.

All contributions are of a scientifically applied and applied nature. They are of such a nature that in addition to their theoretical usefulness, they can also be used in practice, their applicability will undoubtedly be useful for specialists dealing with these problems. This is undoubtedly the great theoretical and practical usefulness of the doctorate, and the experimental results prove in an indisputable way the effectiveness of its future application in practice.

6. Assessment of the degree of personal participation of the dissertation candidate in the contributions

My assessment is that the dissertation work and contributions are the personal work of the doctoral student with the help of his scientific supervisor. The selected methodological tools were experimented with and the results were used to model and simulate the characteristics and dynamics of the sensor, providing an idea of their suitability for various scenarios in robotics. Computer simulation of the electrical circuit was performed in PROTEUS, and the printed circuit board was created in EasyEda. I assume that they are sufficient for this type of scientific research. In addition, the knowledge from the application of this methodology in the search for effective solutions will be enriched.

7. Assessment of dissertation publications

Main achievements and results of the dissertation work have been published in 3 scientific publications, 1 of which is refereed in Scopus, and the other two in a highly rated conference:

- Tzvetkov V. , Valchkova N. , Zahariev R. . "Methodology for Selection and Design of Sensor Systems for Mobile Service Robots". Proc. of the 9th International Conference on Engineering and Emerging Technologies (ICEET), IEEE, 27-28 October 2023, Istanbul, Turkey, , IEEE, 2024, DOI: 10. 1109/ICEET60227. 2023. 10526135, 1-6
- Valchkova N. , Tzvetkov V. , Zahariev R. . "A Service Robot Module Based on 8 Bit Microcontrollers Designed To Measure A Patient's Temperature". Automation of discrete production, 5, TU-Sofia, 2023, ISSN:2682 9584, 40-44
- Tzvetkov V. , Valchkova N. , Zahariev R. . Типове сензори за приложения в роботиката. Automation of discrete production, 6, TU-Sofia, 2024, ISSN:2682 9584, 49-54

From the publications made, I judge that they are all related to the topic and I assume that they are all related to the issues of the doctoral thesis.

8. Assessment of the compliance of the abstract with the requirements for its preparation

The dissertation abstract meets the requirements of the law on the development of academic staff in the Republic of Bulgaria in terms of volume and structure. It faithfully and accurately reflects the goals and objectives of the dissertation work, the content of its individual chapters, the essence of the solutions achieved, respectively, the scientific-applied and applied contributions.

9. Opinion and notes

The dissertation makes a good impression with its in-depth analysis and assessment of the state of the treated problem, with the disclosure of its unresolved aspects, with the justified derivation of the goal and tasks to be solved, with the correct choice of approaches, methodologies and means to achieve the planned solutions, with the good textual presentation of the material and its illustrative design - the work of the doctoral student himself under the guidance of his scientific supervisor. It would be good to clarify the terminology, since in some places an outdated term for "sensor" is used, the relationship between tables 2.1

to 2.6 and the summarized figure 2.1 is not clarified. In the candidate's dissertation I did not find any gaps of a principled or discussion nature, i.e., such as erroneous statements, incorrect generalizations, incorrect use of other people's developments.

10. Conclusion

The dissertation submitted to me for review is dedicated to a topical scientific and scientifically applied problem. I accept the doctorate as completed, giving it a very good grade. These are my reasons for concluding that the requirements contained in the current ZRASRB for the conditions and procedure for acquiring scientific degrees have been fully met. I give a positive assessment of the dissertation and propose to the members of the scientific jury to award its author, M.Eng. Vasil Georgiev Tsvetkov, the educational and scientific degree "doctor" in the professional field professional field 5.2. "Electrical engineering, electronics and automation"

Reviewer:

/prof. Phd. Eng. Pancho Tomov/