REVIEW

of a Dissertation for the educational and scientific degree of

"Doctor"

Author of the dissertation: Svetoslav Emilov Kremenski, MSc Eng.

Dissertation title: **Integration of Brain-Computer Interface and Social Robots with Applications in Various Object Domains**

By Prof. Maya Dimitrova, PhD, IR-BAS, Sofia, Department "Interactive Robotics and Control Systems" (IRCS)

Professional field: 5.2 Electrical Engineering, Electronics, and Automation, Scientific Specialty: Application of the principles and methods of cybernetics in various fields of science

Svetoslav Emilov Kremenski, MSc (Eng.), completed his higher education at the Technical University of Sofia, obtaining a Bachelor's degree in Telecommunications in 2016 and a Master's degree in Radio Communications in 2018. He enrolled in a full-time doctoral program at the Institute of Robotics, BAS, on January 1, 2020. An order (No. 125B/17.12.2024) has been issued by the Director of the Institute of Robotics (BAS) regarding the completion of his doctoral studies with the right to defend his thesis. He currently holds the position of Chief Engineer at A1 Bulgaria.

1. General description of the dissertation and the materials accompanying it

The dissertation spans 177 pages, contains 35 figures and 2 tables, and comprises an introduction, four chapters, a conclusion, directions for future work, a summary of the dissertation's contributions, a list of references, and three appendices. The literature cited includes 138 publications covering contemporary research in neuromarketing and programming for the Internet of Things. Overall, the bibliography is sufficient and appropriate for the objectives set out in the dissertation.

2. Relevance of the problem

Integrating brain-machine/computer interfaces (BCIs) and social robots within the context of neuromarketing is a highly relevant area of research into consumers' explicit or implicit attitudes—both regarding a specific product and in relation to the method of persuasion used to enhance its appeal.

This dissertation addresses the evident need for such systems by proposing an innovative methodology for transforming social robots into "Internet of Things" (IoT) devices capable of applying neuromarketing principles during user interactions. A system has been

implemented that aligns with modern approaches involving the transmission of EEG signals to cloud platforms for rapid brain activity analysis; simultaneously, the robots utilize cloud-based Natural Language Processing (NLP) services to convert preferences and intentions into speech, thereby ensuring ergonomic and safe human-robot collaboration in both domestic and industrial environments.

The subject of the research in this dissertation is the process of integration between BCI and social robots as Internet of Things (IoT) objects, aimed at enhancing their communication for applications in the field of neuromarketing.

3. Knowledge of the state of the problem

PhD candidate Eng. Svetoslav Kremenski is thoroughly familiar with the state of the problem under consideration. He draws upon a bibliography of 138 English-language sources covering the fields of neuroinformatics and programming for the Internet of Things. The dissertation comprises an introduction, four chapters, a conclusion, and directions for future research.

Chapter 1 presents an overview and analysis of brain-machine interfaces and social robots with applications in various fields, identifying a lack of compatibility between brain-machine interface communication channels and Internet of Things (IoT) objects on the one hand, and existing commercial social robots on the other. The **objective of the dissertation** is formulated as follows:

To develop and validate a universal methodology for integrating various BCI devices and social robots into the Internet of Things, which can be used to predict preferences and intentions in the field of neuromarketing.

To achieve this goal, 4 main tasks have been set:

1) Analysis of existing research in the dissertation's subject area and a study of existing BCI devices, social robots, and their potential application areas.

2) Systems analysis of existing software platforms for integrating EEG-based brain-computer interfaces and social robots into the Internet of Things (IoT); investigation of methods for transforming social robots into IoT "things" based on their hardware and software configurations; investigation of machine learning methods for characterizing and classifying brain activity during decision-making or selection processes.

3) Research and design of a new methodology for integrating BCI and social robots into the Internet of Things across various application domains. Development of novel methods and algorithms for integrating various BCI devices and social robots using the Node-RED platform.

4) Validation of the proposed methodology using an OpenBCI device and the Furhat social robot, with an application in the field of neuromarketing to study consumers' spontaneous emotional reactions to advertised products and their choices. Development of experimental and demonstration software.

4. Approach and solution to the problem

These tasks are addressed in depth and analytically in the chapters of the dissertation. Chapter 2 presents a systematic study of software methods for designing and integrating an EEG-based brain-machine interface and social robots within the Internet of Things. Chapter 3 presents the original methods and algorithms developed for integrating the brain-machine interface and social robots.

Of particular significance is the proposed new approach utilizing derivatives (first and second) of EEG signals or EEG power within frequency bands—which can reveal nonlinear dependencies—as well as a new neuromarker based on the Pearson correlation between the second time derivatives of EEG power across different electrodes during the early brain response interval (50–200 ms).

Chapter 4 describes the experimental testing and verification of a methodology for predicting consumer choices based on the integration of an EEG-based brain-computer interface and the Furhat social robot for intelligent neuromarketing.

5. Main Contributions

Six main scientific and applied contributions of the dissertation have been formulated, which I fully accept.

1. A new conceptual model for interaction with social robots via EEG signals in an IoT environment has been developed and implemented using the Node-RED platform. The key functional requirements for the transmission, analysis, and processing of EEG signals, as well as their conversion into control commands for social robots, have been formulated.

2. Original methods and algorithms have been developed to easily transform social robots into IoT devices—for Pepper via MQTT and Python subprocesses in Node-RED, and for Furhat via the HTTP protocol using GET/POST requests from the behavior control software module, processed in Node-RED by an HTTP input node.

3. An IoT-based architecture has been developed for the integration of an EEG-based BCI and social robots; implemented in Node-RED using ready-made nodes for EEG devices and visual programming, it ensures dynamic management of hardware and software resources and asynchronous data exchange through the execution of external Python child processes.

4. In the field of neuromarketing, new methods and algorithms have been developed to analyze the dynamic similarity of spatiotemporal EEG signals—reflecting spontaneous consumer reactions—by extracting features based on the second derivatives of signal power.

5. Based on these algorithms, a new neuromarker for assessing consumer choice has been defined, utilizing Pearson correlation within sliding windows. It measures the spatiotemporal similarity of responses (up to ~2 seconds) and offers a computationally less intensive alternative to classical wavelet analysis and the Fourier transform.

6. A methodology and software for real-time neuromarketing research has been developed and experimentally verified through the integration of OpenBCI and the social robot Furhat. By combining sliding-window dynamic similarity analysis and statistical analysis (Cohen's d with 95% confidence intervals), key electrodes and frequency bands reflecting spontaneous emotional reactions during consumer choice were identified.

The contributions presented in this way can forward fundamental aspects the overall framework of the dissertation's research on intelligent communication—encompassing brain-computer interfaces and social robots that leverage the potential of large language models for the in-depth interpretation of human preferences and intentions in socially motivated decision-making situations.

I consider the approaches adopted and the solutions implemented by the author to be appropriate for achieving the objective and the tasks formulated in the dissertation, a view confirmed by the results obtained.

6. Reliability of the obtained results

Modern tools and techniques were employed to address the tasks at hand, including software programming, cluster modeling, neural networks, mathematical statistics, and others. I consider the research presented in the dissertation—specifically the methods of engineering

reliable and sufficient to warrant the award of the educational and scientific degree of "Doctor."

7. Publications related to the dissertation topic

Two published papers related to the dissertation and one article currently in press are presented. The doctoral candidate is the first author of a paper from an international IEEE conference indexed in Scopus, as well as a co-author of an article in a journal with an impact factor. Five citations in prestigious publications have been recorded; this exceeds the requirements and serves as an independent indicator of the research perspective.

8. Personal impressions

I know Eng. Svetoslav Kremenski as a colleague at the Department of the Institute of Robotics, BAS. We have no joint research or publications. I definitely believe that Eng. S. Kremenski possesses the necessary qualities and has demonstrated precision, motivation, and thoroughness in conducting research, both independently and as part of a team.

9. Critical remarks and recommendations regarding the dissertation

I have no critical remarks regarding the dissertation, which is very well presented in terms of structure and scientific style.

10. Conclusion

My overall assessment of the submitted dissertation is positive. It is complete in terms of both scope and content. The doctoral candidate, Eng. Svetoslav Kremenski, has earned the necessary credits in fulfillment of the minimum national requirements, as stipulated in the Law on the Development of Academic Staff in the Republic of Bulgaria (DASRB), the Regulations of the Bulgarian Academy of Sciences (BAS), and the Internal Rules of the Institute of Robotics at BAS.

Based on my review of the submitted dissertation and the contributions contained therein, I consider that the work fully meets the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria and the Regulations on the Procedure and Conditions for Acquiring Academic Degrees at the Bulgarian Academy of Sciences. All requirements for obtaining the educational and scientific degree of Doctor have been fulfilled.

Sofia, 2.07.2026 Signature: