STATEMENT OF OPINION

on a Dissertation for gaining the educational and scientific degree of **Doctor**

Thesis topic:

"DESIGNING A BRAIN-MACHINE INTERFACE FOR VARIOUS DEVICES AND SERVICES IN THE INTERNET OF THINGS"

Professional field 5.2. Electrical engineering, electronics and automation

Scientific discipline "Application of the principles and methods of cybernetics in various fields of science"

Author of the thesis: M. Eng. Adelina Georgieva Kremenska

Member of the scientific jury: Assoc. Prof. Mila Ilieva-Obretenova

The dissertation submitted for reviewing is 134 pages long. The content is structured as follows: Introduction, Four Chapters, Conclusion, Prospects for future work, Contribution of the dissertation, Sources, Appendices, 34 figures, 5 tables.

1. Relevance of the problem developed in the dissertation in scientific and scientific-applied terms

According to a new forecast of IDC (International Data Corporation), it is estimated that in 2025 there will be 41.6 billion connected IoT devices or "things" (IoT - Internet of Things). People will be able to interact with and control a wide range of everyday devices through different interfaces: via smartphone apps, smart glasses, voice, gestures or new alternatives such as Brain-Computer Interface (BCI) or in Bulgarian: Brain-Machine Interface (MMI). The massive penetration of connectivity of everyday devices and the development of mobile non-invasive MMI based on encephalography (EEG) will enable people to control directly, through their thoughts IoT "things", such as appliances or assistive robots, in their smart houses. However, realizing such thought interactivity between people and "things" faces a number of challenges, the most important of which is correctly interpreting people's intent to encode raw EEG brain signals. These are often of low accuracy due to noise, lack of human concentration, or lack of an operational protocol for the use of the MMI device. The protocol must set the configuration of the number of EEG channels and their location, the software training, and the

timing characteristics to capture the intent. Pre-processing the brain signals and then classifying and translating them into IoT commands to devices and services requires the teamwork of neuroscientists, bio-medical engineers and computer scientists. Very often this collaboration is not possible and researchers experience difficulties when trying to use available software tools "for general purposes" as additional programming skills are required. On the other hand, computer scientists face difficulties in designing customized MMI applications for IoT due to lack of neurological expertise and universal EEG features. Most developed MMI applications are for a specific MMI device and purpose. Another challenge to "brain to IoT object" communication is the lack of compatibility between the different devices and software in IoT. IoT data transmission and management require the use of specific protocols such as MQTT, OPC UA, etc. Due to the growing trend for open source software in IoT, new opportunities for connectivity between people and "things" are unlocked thanks to devices providing open source applied programming classes that can be accessed without having to use specific protocols. Open source is the key to faster progress in the field as it facilitates sharing of best practices and engages more resources in R&D.

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

The PhD student shows a thorough knowledge of the state-of-the-art about the studied matter. The dissertation uses 102 sources, all of which are in English. The sources cited are relevant to the dissertation topic. Most of the literature sources used are from the last 10 years. All sources are cited correctly in the dissertation.

3. **Conformity of the chosen research methodology with the stated aim and objectives of the dissertation and with the achieved contributions**

I believe that the methodology chosen by the PhD student: Research, Design and Development of an innovative model providing an intelligent and user-friendly approach for registering and interpreting brainwaves in the Internet of Things fully corresponds to the goal set in the dissertation: *"To create a system architecture built on a new conceptual model for the design of a Brain-Machine Interface (BMI), applicable to different EEG devices and services in IoT, in which a new open source software toolkit for the development of BMI applications in IoT through a graphical visual programming interface will be integrated"*. For the realization of the set goal, the PhD student has clearly formulated 4 main tasks which are fulfilled in the thesis.

4. Evaluation of the author's long abstract and publications related to the dissertation

The long abstract fully complies with the requirements of the "Law on the Development of Academic Staff in the Republic of Bulgaria - LRAADB" and the Regulations for the Application of LRAADB. Its structure and content are in line with what is presented in the thesis. The main results of the dissertation have been published in 4 articles in the period 2022-2024. The publications are in co-authorship. Two papers were presented at conferences: 1. International Conference on Software, Telecommunications and Computer Networks (SoftCOM). IEEE, 2024 (in print), 2. International Conference on Information Technologies (InfoTech), Varna, Bulgaria, 2022, SJR(2020)=0,147. Two papers have been submitted to journals: 1. Preprint in Journal of Open Access 2024, 2. International Journal on Information Technologies and Security (IJITS), 2024, IF(2022)=0.9. One of the papers has been cited twice in prestigious scientific journals. Publication activity is described completely in the dissertation.

The data from the submitted materials on the research and publication activities of M. Eng. Adelina Georgieva Kremenska show that the PhD candidate fulfills the minimum national science-metrics indicators for obtaining the educational and scientific degree of Doctor.

5. Evaluation of the scientific results and contributions and the degree of personal involvement of the PhD student in the studied subject matter

The contribution in the dissertation can be divided into contribution of scientific-applied nature and applied nature. The doctoral candidate has formulated 1 contribution of scientific-applied nature and 4 of applied nature. All contributions are adequately justified.

The schematic solutions, model, system architecture, algorithm block diagrams and experimental studies presented by the PhD student enable the improvement of the applications for Brain Machine Interface in IoT by integrating a new software toolkit for the transmission of EEG data, features and metrics. At the same time, the candidate developed a protocol for ethical experimental studies of the degree of concentration which will enable the correct interpretation of people's intention encoded in EEG brain signals.

The PhD student's personal involvement in the research process and in the development of the dissertation has been substantial and significant.

6. Comments, criticisms and recommendations

There were some editorial errors in the thesis, which were highlighted and corrected.

In spite of the above criticism, I believe that the author has demonstrated knowledge and skills in conducting the research, processing the results and synthesizing the contribution in the dissertation. This is an excellent testimonial for the PhD student and her supervisors and warrants a positive evaluation of the overall presentation of the dissertation.

7. Conclusion

The dissertation presents in detail the author's research, which is of an undisputed scientific-applied and applied nature.

The submitted dissertation, the author's publications and the correctly formulated contribution have merit and I believe that they fully comply with the requirements of the "Law on the Development of Academic Staff in the Republic of Bulgaria - LRAADB" and the Regulations for the Application of LRAADB.

I give a positive evaluation of the dissertation and propose that the esteemed scientific jury M. Eng. Adelina Georgieva Kremenska is awarded the educational and scientific degree of Doctor in professional field 5.2. Electrical Engineering, Electronics and Automation, Scientific discipline "Application of the principles and methods of cybernetics in various fields of science".

13.09.2024

Member of the Scientific Jury:.....

(Assoc. Prof. Dr. Eng. Mila Ilieva-Obretenova)