OPPONENT'S REPORT ON THE DOCTORAL DISSERTATION

Doctoral Candidate: Ing. Filip Černý
Study programme: Biomedical Engineering
Supervisor: doc. Ing. Marek Piorecký, Ph.D.

Czech Technical University in Prague – Faculty of Biomedical Engineering

Title of the Dissertation:

Optimization of the Closed-Loop Acoustic Stimulation of Deep Sleep Method

1. Relevance and Timeliness of the Topic

The dissertation addresses the optimization of closed-loop acoustic stimulation (CLAS) of deep sleep, with a specific focus on the detection and phase-targeted stimulation of slow oscillations during NREM stage 3 sleep. The topic is clearly relevant and well aligned with current research directions in biomedical engineering and neuroscience. The importance of sleep quality for cognitive functioning, memory consolidation, and overall health is well established, and CLAS represents a promising non-pharmacological approach to sleep modulation. The emphasis on individualized detection strategies reflects a thoughtful response to known limitations of existing methods and corresponds well with current trends toward personalized biomedical technologies.

2. Objectives of the Dissertation and Their Fulfilment

The objectives of the dissertation are clearly formulated through four main hypotheses that guide the research from data analysis to algorithm development and experimental validation. The structure of the objectives is logical and coherent. Based on the presented results, the stated objectives were largely fulfilled. The individual hypotheses were addressed in a systematic manner, and the results provide convincing support for the proposed individualized detection approach.

3. Methodology and Technical Approach

The methodological approach of the dissertation is appropriate and well designed. The analysis of large EEG datasets spanning different age groups and clinical conditions provides a solid empirical basis for the development of the individualized **I-TOPO algorithm**. The algorithmic development and validation strategy, including offline restreaming of polysomnographic data and subsequent implementation in a sleep laboratory environment, is well thought out and technically sound. The pilot experimental study, although limited in sample size, was conducted according to established standards in CLAS research and provides meaningful preliminary evidence of the method's effectiveness. Overall, the methodology supports the conclusions drawn, while clearly leaving room for further validation in larger-scale studies.

4. Use of Scientific Literature

The dissertation demonstrates a good to very good knowledge of the relevant scientific literature. The candidate appropriately reviews and contextualizes existing CLAS methodologies and detection algorithms. The cited sources are relevant and sufficiently up to date, and they are used in a meaningful way to motivate methodological choices and to interpret experimental findings. The literature review adequately supports the scientific framework of the dissertation.

5. Results and Scientific Contribution

The results indicate that the proposed I-TOPO algorithm improves the sensitivity of slow oscillation detection while preserving phase accuracy and physiological signal characteristics. The observed enhancement of both slow oscillation and sleep spindle activity following stimulation is a noteworthy and promising finding. Although the results are primarily based on a pilot experiment, they represent a meaningful methodological contribution and provide a solid foundation for future research. The scientific contribution of the dissertation can thus be regarded as clear and relevant, particularly in terms of algorithm development and experimental feasibility.

6. Formal, Linguistic, and Graphical Quality

The dissertation is well structured and clearly written. The scientific style is appropriate, and the text is generally clear and comprehensible. Minor linguistic and typographical issues occur occasionally but do not affect the overall readability or scientific content. Figures and tables are relevant and helpful in illustrating the results and methodological steps

7. Evaluation of Publication Activity

The publication activity of the doctoral candidate is very good and fully consistent with the standards expected for doctoral studies at CTU FBMI. The candidate is the co-author of several peer-reviewed publications, including two journal articles published in internationally recognized journals—one in a Q1-ranked and another in a Q2-ranked journal—as well as four peer-reviewed conference papers. This publication record clearly demonstrates the candidate's ability to conduct independent research at an internationally competitive level and to produce scientifically valuable results suitable for dissemination within the global scientific community. The quality and scope of the presented research also indicate good potential for further publications in peer-reviewed international journals.

8. Critical Remarks

The following remarks should be considered:

- The pilot nature of the experimental study and the relatively small sample size limit the generalizability of the findings.
- The functional impact of the stimulation on cognitive or behavioral outcomes is discussed mainly indirectly and could be addressed more explicitly in future work.
- Further discussion of computational demands and long-term stability of the algorithm in real-world applications would be beneficial.

These remarks are intended as constructive suggestions for further development rather than fundamental criticisms.

9. Questions for the Defense

1. What are the main challenges associated with dynamic updating of individualized templates during a single night of recording?
2. How robust is the I-TOPO algorithm when applied to EEG data with pronounced artifacts or pathological features?
3. What would be the next steps to translate this methodology into larger clinical or longitudinal studies?
4. How do you interpret the possible effects of the stimulation on the detected sleep spindelsss?

10. Overall Evaluation According to CTU-FBMI Criteria

Evaluation Criterion	Assessment
Relevance and originality of the topic	Excellent
Fulfilment of dissertation objectives	Excellent
Methodological and technical quality	Excellent
Scientific contribution	Excellent
Use of literature	Excellent
Formal and linguistic quality	Very good
Publication potential	Excellent

11. Final Recommendation

The doctoral dissertation meets the formal and scientific requirements for a doctoral thesis at the Faculty of Biomedical Engineering, Czech Technical University in Prague. The candidate has demonstrated the ability to carry out independent scientific research and has contributed original and meaningful results to the field.

I strongly recommend the dissertation for defense.

Praha, 27 December 2025

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