UFE Institute of Photonics and Electronics
The Czech Academy of Sciences

Doctoral thesis review from the reviewer Michal Cifra

Title of the doctoral thesis:
Microwave stroke detection and classification using machine learning algorithms and realistic models of the human head

Author of the doctoral thesis:
Ing. Tomáš Pokorný

1. Relevance of the dissertation topic

The topic of "Microwave stroke detection and classification using machine learning algorithms and realistic models of the human head" is highly relevant in the field of biomedical and clinical engineering. Stroke is a leading cause of death and disability worldwide, and early detection and accurate classification of stroke types are crucial for effective treatment and patient outcomes.

2. Fulfillment of the objectives of the dissertation

The goals of the dissertation thesis have been fulfilled. Machine learning algorithms were systematically tested in microwave detection and classification of strokes using realistic models of the human head. Large datasets were obtained through numerical simulations and experimental measurements on phantoms. A methodology for measurement and data storage was developed. Algorithm performance was evaluated through defined test scenarios, investigating the effects of factors such as data reduction, dimensionality reduction, algorithm selection and configuration, and frequency range variation. The achieved results contribute to advancing pre-hospital stroke diagnosis using microwave-based techniques.

3. Methods and approaches used in the solution

The methods used in the thesis are appropriate and aligned with the study's objectives. The combination of numerical simulations and experimental measurements allowed for comprehensive data generation and validation. Using the COMSOL Multiphysics simulator and MATLAB scripts, synthetic datasets with varying stroke positions and sizes were created. Genetic algorithms optimized the antenna model for accurate transmission parameter agreement. The validation process involved comparing synthetic and measured S-parameters and analyzing magnitude differences between 2D and 3D models. Experimental measurements using laboratory prototypes and 3D-printed phantoms enriched the dataset. Feature selection and dimensionality reduction techniques, such as Lorentz reciprocity and PCA, were employed for data analysis. The SVM algorithm demonstrated its capability in stroke classification, outperforming statistical probability, and was tested under various scenarios. Overall, the methods and procedures applied in the thesis align well with the research objectives and effectively contribute to stroke classification research.

4. Results of the dissertation and specific contributions of the author

This thesis investigated the potential of support vector machines (SVM) for microwave stroke detection and classification. Validated numerical models and experiments generated large datasets with varying data variability. The results confirmed SVM's ability to detect strokes and classify them as ischemic or hemorrhagic subtypes. Principal component analysis (PCA) improved classification results and simplified measurement hardware. Datasets with both transmission and reflection coefficients performed better, and real/imaginary part representation outperformed module/phase representation. Accurate stroke detection and classification remain challenging due to data variability. However, the SVM algorithm showed promising accuracy in classifying ischemic strokes, enabling safe initiation of thrombotic therapy in 70% of patients. Further research is needed to enhance sensitivity and improve clinical applicability.
The specific contributions of the author should be clarified, see my comment lower.

5. Significance for practical application and development of the field of Biomedical and Clinical Engineering
   This thesis significantly contributes to the field of Biomedical and Clinical Engineering by investigating the potential of machine learning algorithms for stroke detection and classification.

6. Formal arrangement of the dissertation and its language level
   The thesis arrangement is appropriate and the language level is of high quality apart from few typos ("S-paremeter", "nineth", ...).

7. Comments and final evaluation of the dissertation
   1. I could not find anywhere in the thesis materials what were the specific contributions of the author – could you clarify which parts of the thesis were more collaborative and which mostly your work ?
   2. p. 17. "dielectric properties of YYYY are approximately XX % higher" it would be better to be specific which property is considered, in principle "dielectric properties" could refer to real or imaginary part of the permittivity, susceptibility, refractive index, tan Delta, conductivity....
   3. Apart from the S-parameter values, did you ever check the EM field distribution and propagation in the brain tissue or performed any analysis of EM field – what insights could it bring ?
   4. Can you make a quantitative guess, maybe based on other literature, what improvement in sensitivity and specificity could be achieved via a planned quasi-spherical arrangement ?

Overall, the thesis is of a high quality and I recommend its defense.

Prague, 25th May, 2023
Ing. Michal Cifra, PhD.

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Signature