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Review of doctoral thesis

Ph.D. student: Ing. Valeriia Trukhan

Study title: Detection of artifacts in arterial blood pressure and intracranial blood pressure signals

The dissertation of Ing. Valeriia Trukhan focuses on the detection of artifacts in biological signals, specifically in directly measured (invasive) arterial blood pressure (ABP) and intracranial pressure (ICP) signals. Within the scope of the dissertation, an algorithm for artifact detection based on Short-Time Fourier Transform (STFT) was developed.

Relevance of the Dissertation Topic

The dissertation topic is highly relevant. Automatic processing and evaluation of biological signals are gaining increasing importance, particularly in intensive care medicine.

Fulfillment of Dissertation Aims

The aim of the dissertation is to develop an algorithm for detecting artifacts in arterial blood pressure and intracranial pressure signals.

The primary objective is to detect and eliminate artifacts in the arterial blood pressure signal, as these artifacts significantly affect the calculation of the pressure reactivity index (PRx) more than artifacts in the intracranial pressure signal. The secondary objective is detecting artifacts in the intracranial pressure signal.

Another objective is to create a plug-in for the ICM+ software, which outputs a PRx reliability index, informing clinicians about the percentage of artifacts present in a given time interval.

All stated objectives of the dissertation were met.

Methods and Procedures

In the course of the dissertation, the following steps were undertaken:

- Pseudonymization of data recorded using ICM+ software.
- Examination of the effect of downsampling, performed by ICM+ software, on the frequency spectrum of ABP and ICP signals, as well as the circadian variability of the PRx index.
- Simulation of artifacts and investigation of the effect of high-frequency artifacts on the PRx index.
- Selection of a time window for artifact detection using STFT.

- Development of an algorithm for detecting simulated artifacts. The algorithm was initially tested on simulated stereotypical artifacts in ABP signals and then validated on real ABP data with manually labeled artifacts.
- Finally, a plug-in for the ICM+ software was developed in Python, integrating the artifact detection algorithm. Its output includes a PRx reliability index, representing the percentage of artifacts in a given time interval.

The methods and procedures used were appropriately chosen for the problem being addressed.

Dissertation Results and Contributions of the Author

The following results were achieved by the author during the dissertation:

- New HDF5 files with complete pseudonymization were created using a script.
- It was determined that downsampling to 100 Hz during the export of ICM+ data to HDF5 format does not affect the frequency spectrum of ABP or ICP signals, as both signals have maximum frequencies below 50 Hz.
- Increased variability in the PRx index was observed during morning and evening hours; however, it was not possible to determine the extent to which this variability is associated with the presence of artifacts.
- Two main types of artifacts were identified: stereotypical and complex. Based on shape, duration, and amplitude changes, five types of stereotypical artifacts were described: rectangular, rapid impulse, sawtooth, isoline drift, and constant ICP value. Mathematical models of these five artifact types were created in MATLAB and inserted into segments of intact ABP and ICP signals at precisely defined times. It was found that rectangular and sawtooth artifacts lead to significant changes in the PRx index, while rapid impulse, isoline drift, and constant ICP value artifacts do not significantly affect the PRx index.
- It was determined that high-frequency artifacts in invasive arterial pressure in the range of 5–25 Hz do not significantly influence the calculation of the PRx index.
- A 5–7 second time window for STFT was found sufficient for detecting changes in ABP and ICP signals.
- An algorithm for artifact detection was developed, which demonstrated high specificity for identifying artificial artifacts and high sensitivity for rectangular and sawtooth artifacts. Very low sensitivity was noted for baseline drift artifacts, while rapid impulse artifacts were not detected at all.
- To apply the algorithm to real data, significant modifications and fine-tuning were necessary. After these adjustments, the algorithm achieved 92% sensitivity and 90% specificity for artifact detection in ABP signals. In ICP signals, the algorithm achieved approximately 80% sensitivity and specificity for artifact detection.
- Finally, a plug-in based on the developed algorithm for detecting ABP artifacts was

created in Python for the ICM+ software. The plug-in outputs the PRx reliability index, representing the percentage of artifacts detected in ABP signals during a given time interval.

Practical Significance and Contribution to Biomedical and Clinical Engineering

Automated processing of biological signals and improving the accuracy of their evaluation has significant practical importance in medicine. Artifacts can greatly influence the results of signal analysis, leading to skewed measurements and potential misinterpretation, ultimately resulting in diagnostic errors. The results of the dissertation can help automate data evaluation and improve the accuracy of outputs provided by vital function monitors.

Formal Presentation and Language Level

The dissertation meets all formal requirements, and its presentation and language level are good. Minor formal errors were identified, such as repeated text on page 68, the non-alphabetical arrangement of the list of abbreviations, and inaccuracies in figure numbering in Chapter 5.

Comments and Final Evaluation

Overall, the dissertation is of high quality, and its objectives have been achieved. I recommend the dissertation for defense.

Question of Reviewer

Based on what criteria was the time of 5-7 seconds evaluated as the most suitable interval for the computational window for STFT?

MUDr. Martin Müller, Ph.D.