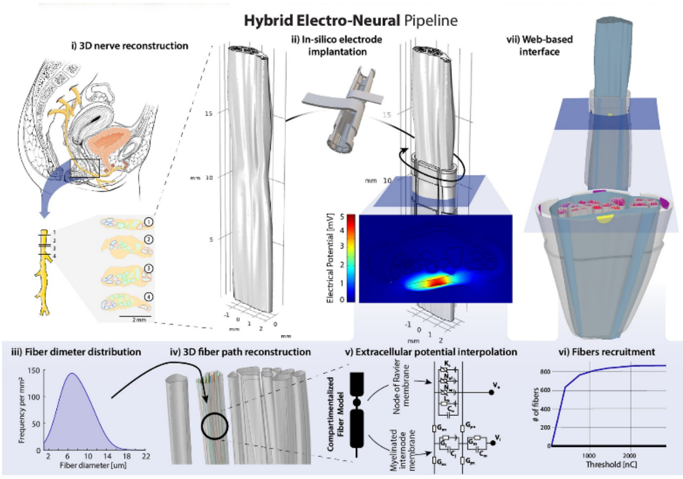
MEDICAL UNIVERSITY OF VIENNA

Prof. Stanisa Raspopovic, Neuroengineering Lab,
Center for Medical Physics and Biomedical Engineering,
Comprehensive Center for AI in Medicine,
Medical University of Vienna
Tel. + 43 140400 17120

Thesis: Development of an AI-Powered Digital Twin for Vagus Nerve Stimulation

General overview of the project:
This project aims to develop a vagus neuroprosthesis for regulating metabolic disorders



The vagus nerve is a peripheral nerve of the autonomic nervous system (ANS), responsible for parasympathetic regulation. It innervates not only multiple organs, but is also connected to several brain networks. Due to this broad anatomical and functional connectivity, electrical stimulation of the vagus nerve has demonstrated therapeutic potential in a variety of clinical applications, most notably in the treatment of depression and epilepsy. Building on growing evidence that vagus nerve stimulation (VNS) can modulate glucose metabolism as well, this project aims to investigate its application for targeted treatment of type 2 diabetes mellitus, by selectively triggering the vagal pathways of metabolic control. Despite these promising findings, a major limitation hindering clinical translation of VNS is the lack of selectivity. The vagus nerve contains mixed afferent and efferent fibers projecting to multiple organs, and non-selective stimulation often results in off-target effects. **By integrating AI modeling, bioelectronic engineering and experimental research, this project will develop an in-silico VNS model, uncover some of the VNS mechanisms, and create an AI-driven VNS closed-loop system.** This breakthrough approach will pave the way for a novel bioelectronic treatment for metabolic diseases, minimizing side effects while enhancing proper control.

Thesis goals:

This thesis aims to develop a **computational platform that predicts vagus nerve (VN) fibers responses to different electrical stimulation patterns**. We developed a highly realistic model of VNS using the technology we were establishing for 10 years that is based on hybrid FEM modeling. Here we aim to replace complex anatomical and physical models with machine learning that would estimate the responses in less time, while maintaining high accuracy. It will enable rapid, personalized VNS optimization by accounting for individual variability and different neuromodulation devices, enhancing therapeutic outcomes and minimizing side effects. This work will provide a **critical tool for optimizing VNS parameters and guiding the design of novel neurostimulation approaches.**

Side goal:

If willing, the student will also be encouraged to participate in pre-clinical experiments involving pigs, specifically during the implantation of the vagus neuroprosthesis. Their role will be limited to observational support, such as note-taking during the procedures.

Recommended skills:

good programming skills (Python), knowledge of AI and Machine Learning algorithms, signal processing and statistical analysis, FEM, COMSOL; highly motivated, prone to work as part of the bigger team.

Keywords: vagus nerve stimulation, artificial intelligence, machine learning, computational modeling

Time required: Master thesis full time

Prof. Stanisa Raspopovic, Neuroengineering Lab,
Center for Medical Physics and Biomedical Engineering,
Comprehensive Center for AI in Medicine,
Medical University of Vienna
Tel. + 43 140400 17120

Contact Details:

- Titouan Brossy, PhD student, email: titouan.brossy@meduniwien.ac.at
- Dr. Natalija Secerovic, PostDoc, email: natalija.secerovic@meduniwien.ac.at
- Dr. Stanisa Raspopovic, Full Professor, email: stanisa.raspopovic@meduniwien.ac.at

Literature:

- Ciotti, Federico, et al. "Towards enhanced functionality of vagus neuroprostheses through in silico optimized stimulation." Nature Communications 15.1 (2024): 6119.
- Ciotti, Federico, et al. "Design of an adaptable intrafascicular electrode (AIR) for selective nerve stimulation by model-based optimization." PLOS Computational Biology 19.5 (2023): e1011184.
- Jayaprakash, Naveen, et al. "Organ-and function-specific anatomical organization of vagal fibers supports fascicular vagus nerve stimulation." Brain stimulation 16.2 (2023): 484-506.
- Howland, Robert H. "Vagus nerve stimulation." Current behavioral neuroscience reports 1 (2014): 64-73.