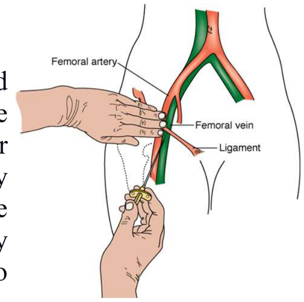
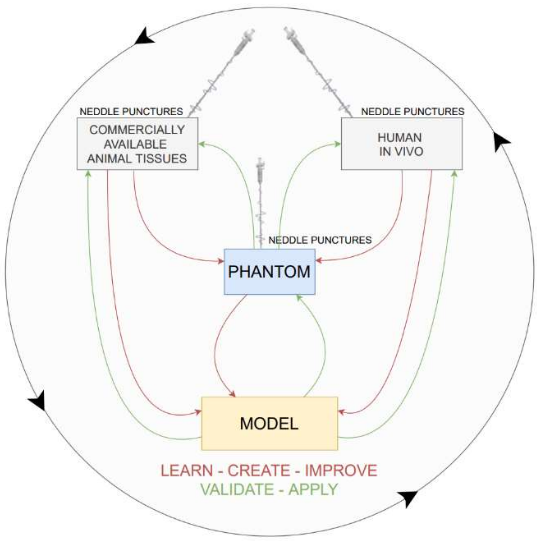
Vibroacoustic sensorics for medical device guidance

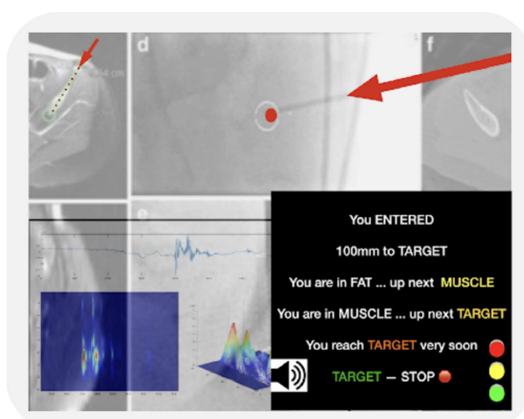


Minimal-invasive medical procedures come with less trauma, small incisions, and faster recovery for the patient. But the clinical devices have to be moved by the clinician accurately to the surgery location and for that rely on external imaging or have a small camera integrated into the tools. A limited field of view (you can only see what is in front of the camera) and imaging artifacts (inaccurate location) make these procedures sometimes difficult to perform for the surgeon. For example, many of the clinical complications are related to the first incision, i.e. creating access to an artery for a catheter procedure or for an abdominal endoscopic procedure.

Vibroacoustic signals are generated through the interaction of the clinical device with human tissue. Depending on the tissue properties (stiffness, roughness, density, water content, etc.) a specific signal (characterized through signal energy, entropy, maximum signal, frequency spectrum, and many more) is generated at the tip of the device, then is propagated through its shaft, and can be measured with a specific audio sensor at the proximal end of the device that is outside the patient's body. This has the advantage that the currently available tools can be used with only little alteration, no cable is in the body, sterilization is relatively easy, and the clinical workflow is not significantly changed. These audio signals could be used to identify significant clinical events (for example crossing different tissue layers, or entering and leaving a blood vessel) and help to accurately guide the device to the desired location. Our previous research showed that some of this is possible in a laboratory setup.



In this project, we now intend to optimize the audio sensors, signal processing, and machine learning using a purpose build phantom that simulates the acoustic properties of human tissues and is guided by the clinical workflow. This should enable us to model a needle intervention accessing the femoral vessels (veinous as well as arterial, with a high clinical need for the venous access as this cannot be palpated in the groin) for a subsequent catheter procedure and verification using actual and real data from clinical interventions. Result-based optimization of the phantom, sensor, processing, and algorithms are the next steps. This will be an iterative research process with the goal to have a laboratory setup that will allow us to build the audio guidance models for this specific clinical application and provide the base for other applications in the future. We anticipate that the developed audio sensor attachment will improve the clinical process boosting the surgeons' confidence and improving procedure quality and speed. Our international research team consists of experts for sensor technology, signal processing, and biomedical engineering at AGH, Kraków, Poland (PI: Prof. Dr. Michael Friebe) as well as on the clinical expertise from renowned radiology and interventional radiology department at the Justus-Liebig-University Hospital in Giessen, Germany (PI: Prof. Dr. Gabriele Krombach) with an impactful history of related joint research in the past.



The proposed research has enormous potential in other adjacent and connected research areas. The obtained vibroacoustic profiles could be used - in combination with machine learning and big data - to possibly determine and classify individual tissues during needle insertion, audio-based histology, that would allow getting a confirmation once a specific target (e.g. a lymph node or an isolated tumor) is reached or would indicate on whether a certain tissue should be removed/treated or not. The audio classification would be additional and complementary to preoperatively or intraoperatively acquired diagnostic imaging information. This could reduce procedure time, improve clinical confidence and surgical quality for an ultimately better clinical result. The acoustic signals could also be used (through event classification and tissue surface analysis) for simulated haptic feedback and improved safety of surgical robotics.