In-situ Tissue Identification by Ultrasonic Pulse Echo Analysis

K. Krasnopolski, R. Limacher

This research aims at the development of a disposable hypodermic needle with embedded tissue identification. The measured response will ensure that specified locations for biopsies, drug dispensing or sensor/actuator placement are reached with superior confidence and false diagnoses or ineffective procedures are prevented. A first proposed application for this smart tool is fine- or core-needle biopsy.

The general motivation of the proposed technology is to add feedback during needle navigation based on viscoelastic properties of tissue either in addition to or as an alternative to imaging techniques. It is expected that this technology will result in an increased success rate of screening and reduced procedural efforts, hence contribute to early breast cancer detection [1] and reduced health care cost. The concept is based on a remote sensing of tissue properties at the needle tip by acoustic emission and response detection at the needle base. Two different acoustic measurement principles are compared using mechanical FEM simulations and simple practical tests: needle resonance and ultrasound pulse-echo analysis.

Both, measurements and simulations, show that the material surrounding the needle body has a strong damping effect on the resonance quality of the needle. Hence, reliable, tip-sensitive tissue classification using needle resonance is very difficult.

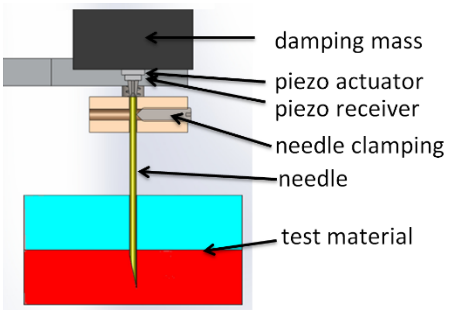

Figure 1: Pulse-echo test setup.

The ultrasound pulse-echo principle (Figure 1) enables spatial discrimination by time-windowing. Moreover, the longitudinal acoustic wave propagation minimizes interaction with tissue along the needle body provided that interface-friction is small. Significant reflection occurs at the needle tip depending on the tip-surrounding tissue.

In order to confirm the promising results of the simulation, various trials were conducted on artificial materials like rubber and silicone. In a first step, test samples made of homogenous materials were investigated. Significant differences in the signal's amplitudes were measured for most of the tested materials, allowing for a clear distinction (Figure 2). In a next step, combined test samples made of two different materials were analyzed to identify the transition from one to the other material. For this purpose, the needle was gradually immersed into the test sample and the signals were extracted related to the penetration depth. The transition between the two materials in the sample could be identified (Figure 3) on the basis of the amplitude's course.

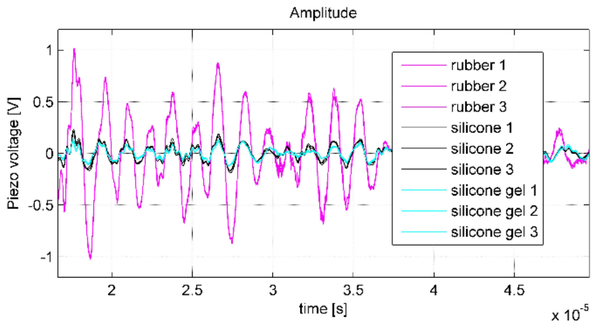

Figure 2: Measured signal for various test materials.

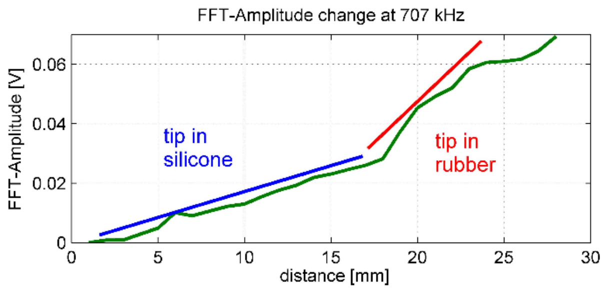

Figure 3: Measured signal at different penetration depth.

In a following step, similar investigations were performed on pig tissues like muscles and fat (bacon). As a result, the system's sensitivity was not sufficient to discern fat from muscle tissue. It is assumed that the characteristic acoustic impedances of both tissues are too similar in comparison with the sensitivity of the current experimental setup. A further increase of the system's sensitivity would require a significant modification of the needle tip and the needle's coupling to the excitation and sensing devices. Consequently, a commercially available disposable needle could not be used—one of the goal of this project. This calls into question the practicability of this method for the planned application area.

In conclusion, it could be shown that the measurement system based on the pulse-echo analysis in combination with a disposable needle allows to identify materials with different characteristic acoustic impedances as well as to detect the transition between two different materials. The applicability of this method for the planned application area is very challenging.

[1] K. Krasnopolski, *et al.*, "In-situ Tissue Identification using Disposable Hypodermic Needles", CSEM Scientific and Technical Report (2013), 89