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30.05.2022

Dear Mr. Rohovets,

thank you for your interest for the research of my group in medical ultrasound imaging. I have attached the description of a research project that is of high interest for us. Parallel to the project we will also train you in ultrasound imaging to build the basis for this research. The research project is planned for a minimum period of 6 months.

I hope that you can join my group soon and we can work together on superresolution imaging.

Sincerely,

  
Prof. Dr.-Ing. Georg Schmitz

Research project proposal:

### **Tracking of microbubbles or blood-cells for superresolution imaging of microvessels**

In the Medical Engineering group, algorithms for ultrasound imaging of microvessels with a resolution beyond the diffraction limit have been developed. The technique used is called motion Model Ultrasound Localization Microscopy (mULM) and needs the administration of ultrasound contrast media, which consist of gas-filled microbubbles. Single microbubbles with only 1-2  $\mu\text{m}$  diameter can be detected and localized with a precision in the order of a tenth of the wavelength. By tracking the detected microbubbles, superresolution images of the microvasculature are generated.

Recently, a novel method was proposed that claims to reach similar resolution by tracking the signals from the erythrocytes in the blood [Jensen2022]. Here, maxima in the speckle pattern generated by the interference of the signals from many erythrocytes are tracked. These maxima are said to be generated only within vessels [Jensen2022] and thus allow to image the vessel borders with high resolution. While it was demonstrated in the work of Jensen et al. that single isolated vessels can be imaged at high resolution, the ability to resolve vessels which are closer to each other than the diffraction limit is not demonstrated.

In the project, which is proposed for a research stay of at least 6 months, the novel method should be investigated theoretically, by simulations and experimentally to investigate its resolution limits. The theoretical investigation will be combined with simulations to investigate the probability of a maximum of the speckle pattern outside the region containing the scattering particles. Simulations are to be performed in the free ultrasound simulation software Field II, for which suitable microvessel models with moving groups of erythrocytes have to be realized. Experimentally, test objects with suitable vessel structures have to be designed and measured with the research ultrasound system Verasonics Vantage 256 available in our lab.

The goal of this research project is a critical evaluation of the interesting new approach by Jensen et al. regarding its performance limits and possibly extensions of the initial idea to allow contrast-free microvessel imaging.

[Jensen2022] Jensen et al. : Fast super resolution ultrasound imaging using the erythrocytes. SPIE Medical Imaging, 2022. DOI 10.1117/12.2612245.