Mission
Computer-support nowadays is ubiquitous in any medical application. It not only helps remove the burden of cumbersome tasks from the shoulders of trained medical personnel, but it also improves the speed and accuracy of several procedures. Computational assistance has a wide range of roles in the medical field, including signal and image processing; modeling, simulation and visualization of procedures; and surgical robotics, sensors, and instrumentation. Accordingly, in advanced medical applications a diverse set of research fields are involved to varying degrees. Bringing cutting-edge scientific innovation into daily clinical routine is a challenging but rewarding goal, which aims to improve the quality of healthcare and hence the overall quality of human life.

The nature of computer-assistance in clinical contexts is varied. Imaging, as a source of large amounts of information, is one area in which computerized solutions can make a substantial difference; both in helping physicians make faster and better decisions, and in creating new diagnostic data enabling more informed clinical decisions through novel image formation and computation techniques. Ultrasound imaging, in particular, which is real-time, cost-effective, and non-ionizing, is an area with a large potential of growth, which has not yet been utilized to its full extent. Therefore, I am particularly interested in ultrasound techniques in medicine. By combining simulation, modeling, signal processing, and computer vision, I imagine that invaluable contributions to healthcare are possible. One specific area of interest is the imaging of internal tissue elasticity, which has indeed been used in medicine as an indication of tissue anomalies for centuries. It is an excellent indication of several types of pathology including cancer. Indeed, palpation of the breast and the prostate are still the most common clinical procedures in screening. The ability to image internal tissue elasticity distributions is an essential addition to the arsenal of doctors.
Research Activities and Achievements

Elastography
One major research direction of the group is the imaging of tissue of elasticity, namely elastography. Past experience in this direction includes work on tissue deformation modeling and precise dense motion tracking, in particular from ultrasound time-series. Inverse problem formulations arise from the fitting of deformation models to tracked motion estimations and can be solved using robust optimization schemes for the approximation of tissue elastic parameters. Figure 1 shows a breast tumor on the left with conventional ultrasound imaging. On the right, the same tumor is seen using a particular elastographic method, where the stiff inclusion is identified clearly. In cases where the tumor is not visible with conventional imaging, tissue elasticity distribution can facilitate tumor identification. Often, whether an inclusion is stiffer or softer is an indication of its malignancy. Local tissue stiffness is also beneficial in monitoring ablation therapies. Additionally, organ stiffness may indicate severe pathologies, such as in liver fibrosis. These are some of the potential clinical applications that are foreseen to benefit directly from our future scientific innovation.

Image Analysis
Segmentation and registration of medical images is of inherent interest to this group. In addition to theoretical work on computed tomography and magnetic resonance imaging, and their clinical applications such as in radiation therapy, ultrasound image analysis is the main focus of our work. Despite its relatively lower signal-to-noise images, a major advantage and differentiator of this modality is its real-time imaging capability. Consequently, often specialized image processing techniques are necessitated to satisfy the robustness and speed demands of ultrasound image modality. For instance, for the automatic measurement of venous pressure using ultrasound imaging, we are currently developing real-time vessel segmentation and tracking techniques to be integrated with an ultrasound-transparent pressure sensing pouch.

Statistical models, machine learning techniques, and graphical and discrete optimization methods are among other tools being studied, aiming to improve accuracy and robustness of medical image analysis methods.

Modeling and Simulation
Modeling and simulation of clinical procedures are essential both for treatment planning and for resident training. A particular application of current interest is the simulation of ultrasound images for training sonographers. This work builds on expertise in ultrasound image formation as well as on patient-specific modeling and virtual-reality simulation. Figure 2 shows a sample simulation framework, in which real-time image simulation is achieved using fast interpolation and rendering techniques based on previously-acquired image data, while a finite-element model is employed to also simulate deformation with transducer interaction in real-time. A sample simulated image is seen in Figure 2 to closely replicate an actual ultrasound image at that presumed location.