Fraunhofer

MARIUS

MAGNETIC RESONANCE IMAGING USING ULTRASOUND

MR-compatible ultrasound research platform for multimodal imaging and a combination of the advantages of MR imaging and ultrasound imaging for ultrasound-supported movement tracking of internal organs during MRT imaging.

BREAST CANCER: COMBINING IMAGING TECHNIQUES FOR QUICKER AND GENTLER BIOPSIES

Taking tissue samples can often be a traumatic experience for breast cancer patients and significant costs are associated with the procedure when magnetic resonance imaging (MRI) is used. Fraunhofer scientists have developed a more cost-effective biopsy method that is easier and gentler to patients. Ultrasound, X-rays, and MR scans cannot answer alone if a breast tumor is malignant. For detailed examination, doctors must often extract tissue samples from an affected area using ultrasound-guided needle biopsy. Unfortunately, around 30 percent of all tumors are invisible to ultrasound. In some cases, MRI is used to ensure correct needle insertion, but needle relocation is often repeated several times before the sample is finally taken. This exhausts patients and is also costly, because the procedure occupies the MRI scanner for a significant period.

The new technique within the MARIUS project requires just one scan of the patient's entire chest once at the beginning of the procedure. The subsequent biopsy is guided by ultrasound, while the initial MRI scan is transformed and accurately rendered on the screen. Doctors would have both the live ultrasound scan and a corresponding MR image available to guide the biopsy needle and display exactly where the tumor is located.

The MRI is performed with the patient lying prone and the biopsy lying on her back. This change of position alters the shape of the patient's breast and shifts the tumor's position significantly. To track these changes accurately, ultrasound probes are attached to the patient's skin to produce two comparable sets of data from ultrasound as well as MR imaging while the patient is in the MRI chamber. While the biopsy is taken in another examination room, the ultrasound probes remain attached, continually recording volume data and tracking the changes of the breast's shape. Special algorithms analyze these changes and update the MR scan accordingly. The MR image changes analogously to the ultrasound scan. When the biopsy needle is inserted into the breast tissue, the doctor can see the reconciled MRI scan along with the ultrasound image on the screen, greatly improving the accuracy of needle guidance towards the tumor.

To realize this vision, a range of new components were developed, such as an ultrasound device that works reliably within an MRI scanner without affecting the MRI scan. Ultrasound probes are also being developed which are attached to the body and provide 3D ultrasound volumes. The software for this technique is completely new to analyze motion in real time by means of ultrasound tracking, recognizing distended structures in the ultrasound volumes, and tracking live tissue deformation. A wide range of sensor data is needed in real time.

MR-compatible Mobile Ultrasound System and Ultrasound Research Platform

This first commercial MR compatible system can be used for ultrasound volume data acquisition in an MR tomograph without disturbing the MR measurements. The beamformer offers 12 bit RF-data of 128 transmit and receive channels with a digitalization of 80 MHz and can use multiple transducers in parallel acquisition mode. Data can be transferred to GPU devices over a PCI-express interface (with 8 lanes) for massive parallel processing and beamforming. Based on this technique modern applications such as ultrafast acoustic imaging and vector-velocity-imaging can be developed. Access ranging from single-element measurement data to filtered ultrasound image output can also be implemented within a unique closed-loop-capable filter interface with easy integration into the overall software system.

MR-compatible, Attachable, Rotating 3D Ultrasound Transducer

Integrated ultrasound transducers were developed that acquire 3D volume data by rotating phased-array blocks. The ultrasound system can control multiple small transducers after attaching them to the tissue using an adhesive tape on an replaceable bayonet cap. The operation frequency of the 3D probes is scalable for different applications based on the used phased arrays or small linear arrays with 128 elements ranging from 2 MHz to 10 MHz.

Adaptive Ultrafast Ultrasound Imaging

The ultrasound beamformer platform being developed is able to dynamically adapt the used scan strategies according to algorithmic feedback within the signal or image processing. It can adjust the volume data acquisition speed and volume resolution depending on the patient’s movement and surpass fixed scanning strategies used in normal clinical scanners. Based on modern ultrafast ultrasound beamforming, the generated images can be built with a very high temporal resolution by only few acoustic excitation events or apply traditional ultrasound beamforming techniques for best imaging quality.

Real-Time 3D Ultrasound to Ultrasound Registration

Local tissue deformation can be monitored by applying real-time motion tracking on ultrasound data acquired in real time. Real time algorithms provide instant estimates of deformation tracked within the current ultrasound 3D volumes.

Organ Deformation Simulation and Information Fusion

Given the sparse and heterogeneous information from ultrasound tracking and additional position tracking sensors, the simulation fuses the data into a realistic real-time shape model of the organ. The model even allows for physically feasible deformation reconstruction of parts within the organ which are not directly assessed by ultrasound tracking or other sensors.

Navigation and Visualization

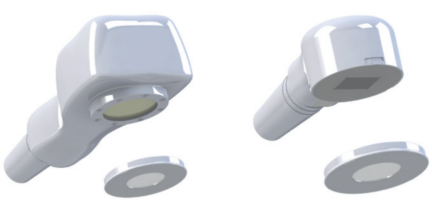
The initially acquired high-resolution MR image can be deformed to match the current tissue shape. Visualization and current ultrasound data, navigators, and markups enable easy 3D navigation and targeting. Following parallel programming paradigms, the whole processing pipeline can be executed in real time.

Breast Cancer Biopsy

By combining the advantages of MR imaging and ultrasound, MRI-guided breast cancer biopsy can be made more precise and significantly accelerated. As only one full MR acquisition is necessary, the tumor can be targeted faster, making the treatment more smooth and cost efficient.

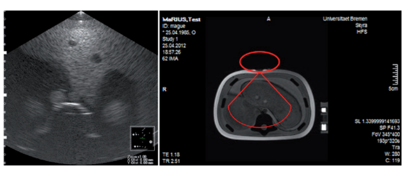
Extension to Other Modalities

Any modality providing additional information about the tissue – PET, SPECT, CT, different MR contrasts – can be registered to the ultrasound image and used to enhance tissue information.



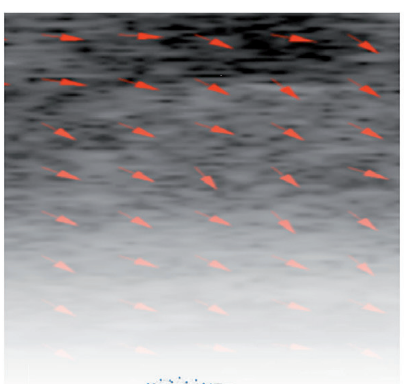
Minimally Invasive Tumor Ablation

Ultrasound MR guidance is of high importance in enhancing the precision of minimally invasive tumor ablation methods such as radio-frequency ablation, cryo-ablation or SIRT.



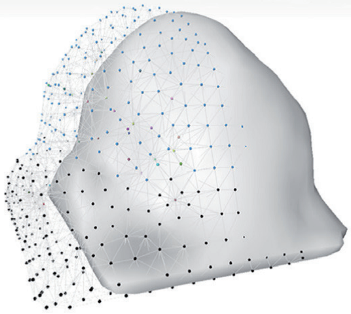
Improving MR Imaging Quality

Patient motion – regular as well as spontaneous – causes severe artifacts in MR image acquisition. Tracking the motion via ultrasound and taking it into account during image reconstruction can improve image quality.



Radiotherapy of Moving Organs

Radiotherapy precision suffers from movement of treated organ during the application of radiation. By supplying the therapy station with real-time tracking information, the quality of the dose placement will be optimized. Thus, surrounding healthy structures such as tissue, vessels, and nerves will be better preserved.



Navigated Open Liver Surgery

Continuous organ motion and soft tissue deformation are the main difficulties within navigated open liver surgery. Using the newly developed combination of 3D ultrasound and deformation tracking, current navigation technology and its clinical relevance will be improved.

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Fraunhofer MEVIS develops interactive assistance systems for clinical routines. This development focuses on medical image data used in early detection, diagnosis, therapy planning, therapy support, or follow-up. In close cooperation with clinical experts, the entire process is considered: from image generation and analysis to interpretation and therapeutic decision-making. From these medical images, diagnostic or treatment-relevant information can be extracted to supplement patient data and laboratory values and individualize them for each patient using biophysical numerical simulations.This contributes to earlier, more accurate disease detection and therapy decisions that are tailored to each patient and evaluated in terms of risk. The success of each therapy becomes more understandable and measurable.

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The Fraunhofer IBMT offers solutions for individual tasks in the areas of biomedical/ medical engineering, molecular and cellular biotechnology and biohybrid technology, cryo(bio)technology and nano (bio) technology, ultrasound technology, neuroprosthetics, (mobile) laboratory technology, sensor technology, health telematics, material testing, home systems as well as industrial process automation and process control. The division ultrasound develops ultrasound systems and methods for a wide range of preclinical, clinical and industrial applications for more than 20 years. For these fields all components ranging from ultrasound transducers, single-channel electronics and multi-channel beamformer hardware, new signal processing algorithms and application-specific software are designed and integrated into systems for industrial and medical systems with clinical approval.