Delft University of Technology
Friday, 26 May 2023

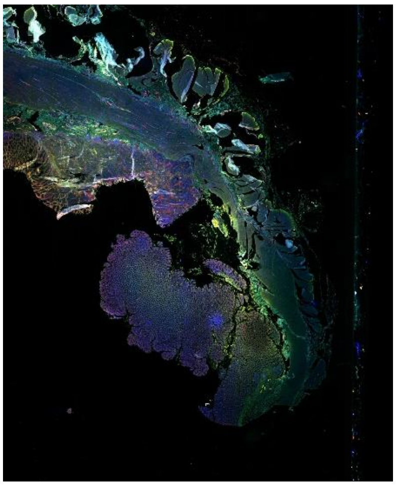
Focus session 'Imaging in several modalities'

Speakers:

- Sjoerd Stallinga (TU Delft): Computational Microscopy for Breaking Fundamental Imaging Barriers
- Srirang Manohar (UT, Tech Med Centre): A dedicated photoacoustic-ultrasound breast imaging system
- Marlies Goorden (TU Delft): Multi-isotope high-energy radiotracer tomography
- Juan Hernandez Tamames (Erasmus MC & TU Delft): Unravelling the Wonders of MRI: A Journey Through the Physics and Applications of Magnetic Resonance in Medical Imaging

Session leader: Silvania Pereira (TU Delft)

Summary of the session
In our present world, we are constantly acquiring, looking at, and analysing images. Image is an important information channel that is almost unavoidable in our daily lives. Images also play a crucial role in both science and technology. When talking about images, one may think on nice photos from our family members and the other pictures that overflows our computers. But there are also images from macroscopic and microscopic objects that cannot be taken by a simple camera. Depending on what you want to see, there are different techniques to acquire these images. Think on images of cells or bones for diagnostics, stars in the sky, microchips, babies inside the body of the mother. For each of these images, there are different techniques and different modalities behind them. In the past centuries, there have been a tremendous progress in the development and improvement of techniques based on light, acoustics, magnetic resonance, and other types of radiation. All of them are being used for different purposes, but with the common goal to improve our knowledge on several fields.



We invite you to take a tour on this wonderful world of fabulous images, and learn what are the techniques behind them and what is waiting us in the future.

The speakers of this session will be: Sjoerd Stallinga (TU Delft), Srirang Manohar (UTwente), Marlies Goorden (TU Delft) and Juan Hernandez Tamames (Erasmus MC).

Fluorescence scan of a large area tissue cut.
Image: Leon van der Graaff, ImPhys afdeling, TNW, TU Delft

Abstracts:

Sjoerd Stallinga (TU Delft): Computational Microscopy for Breaking Fundamental Imaging Barriers

In my presentation I will highlight recent developments by our group in super-resolution microscopy. I will explain how patterned illumination can improve the single molecule localization precision. Next, I will talk about novel ways to extract signal and noise information from a single image, and how that can be used for camera calibration, image resolution measurement, and deconvolution.

Srirang Manohar (UT, Tech Med Centre): A dedicated photoacoustic-ultrasound breast imaging system

Photoacoustic imaging uses nanosecond pulsed light in the near-infrared wavelength regime to illuminate tissue. The light energy is predominantly absorbed by hemoglobin in tissue and converted into ultrasound waves via thermoelastic expansion. These ultrasound waves propagate with low attenuation through tissue and when detected by ultrasound detectors, enable the localization of blood vessels and other tissue absorbers. In a European consortium project, we have recently developed a third-generation dedicated breast imaging instrument in hemispherical geometry based on this technique. One breast at a time of a prone female subject can be imaged in a water-filled imaging bowl whose inner surface has a multitude of laser-light injection points and 512 ultrasound transducers. The bowl and its contents can be rotated around the breast to acquire additional projections. The ultrasound transducers detect the photoacoustic signals, but can also be used to generate ultrasound for transmission-mode tomography. Three-dimensional multi-spectral photoacoustic images and sound-speed images are reconstructed from the acquired projections. The latter images provide actual sound speed values for improved photoacoustic reconstruction. We present an overview of the imaging system and demonstrate its performance on breast phantoms and healthy volunteer breasts. We discuss some of the applications that have been planned using the device.

Marlies Goorden (TU Delft): Multi-isotope high-energy radiotracer tomography

PET and SPECT are molecular imaging techniques that are used both in the clinic and in research labs to image three-dimensional distributions of radio-labeled molecules (radiotracers). Preclinical PET and SPECT are key for developing pharmaceutical drugs, radionuclide therapies and novel diagnostic radiotracers. In recent years the application of radiotracers that combine a predictive biomarker with a therapeutic agent (theranostic tracers) and the need for multi-tracer imaging are witnessing an impressive growth. This challenges conventional SPECT and PET scanners that can only image part of the radiotracer portfolio; conventional SPECT is suitable for imaging one or multiple single-gamma emitters in the 30 keV~360 keV energy range while PET can solely image single positron emitting isotopes. In this talk I will address how novel high-energy clustered pinhole technology combined with accurate photon transport modelling in image reconstruction enables quantitative high-resolution imaging for virtually any available gamma, positron or co-emitting tracer molecule in the 30 keV-1 MeV energy range as well as combinations of these tracers. In vivo sub-mm resolution images of different radiotracer combinations in mice will illustrate the capabilities of this technique.

Juan Hernandez Tamames (Erasmus MC & TU Delft): Unravelling the Wonders of MRI: A Journey Through the Physics and Applications of Magnetic Resonance in Medical Imaging

Magnetic resonance imaging (MRI) has revolutionized the field of medicine since its inception, offering non-invasive, high-resolution images of the body's internal structures. The journey of MRI can be traced back to the 1930s when Isidor Rabi first observed the phenomenon of nuclear magnetic resonance (NMR) inspired by an outstanding Dutch Physicist: Cornelis Jacobus Gorter . Subsequently, in the 1940s, physicists Felix Bloch and Edward Purcell refined the understanding of NMR, ultimately laying the foundation for the development of MRI.

MR “Imaging” was proposed in the 1970s by Paul Lauterbur with additional relevant contributions from many others such Peter Mansfield and Raymon Damadian. Over the years, MRI has evolved into a sophisticated imaging technique that relies on strong magnetic fields, radiofrequency pulses, and advanced computer algorithms implementing the same mathematical framework than, for instance, in radio astronomy but to generate detailed images of soft tissues, organs, and the nervous system making visible the invisible.

The fundamental principle behind MRI involves the interaction between magnetic fields and hydrogen atoms present in the body's water molecules. When placed in a strong magnetic field, these hydrogen atoms align with the field, creating a net magnetization. Radiofrequency pulses then temporarily disrupt this alignment, causing the atoms to resonate at specific frequencies. As the atoms return to their original alignment, they emit signals that are detected by MRI scanners, and these signals are then processed to create images.

MRI has found applications in various medical disciplines due to its ability to differentiate between tissue types. In neuroscience, it is invaluable for visualizing the brain at work: feeling, thinking and reorganizing to be adapted to a permanent environment in change. In oncology, MRI allows for precise localization of tumors and assessment of treatment response.

Advanced applications of MRI include functional MRI (fMRI), which measures brain activity by detecting changes in blood flow, and diffusion tensor imaging (DTI), which maps the diffusion of water molecules in the brain to reveal white matter tracts.

In summary, MRI has come a long way since its early beginnings and continues to impact medical diagnostics and patient care significantly. Its historical origins, basic principles, and advanced applications make it a cornerstone of modern medicine.