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Guest Editorial

Novel Techniques in Instrumentation, Image Reconstruction, and Applications in Magnetic Particle Imaging

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Abstract

The second issue of the fourth volume of the International Journal on Magnetic Particle Imaging (IJMPI) presents 4 papers, comprising a variety of topics in magnetic particle imaging (MPI) including instrumentation, image reconstruction, and applications. These original research papers target the need for dedicated MPI phantom preparation, enable system matrix compression and multiresolution image reconstruction, confirm the feasibility of combining high intensity focused ultrasound (HIFU) with MPI, and propose a novel geometry for a field free line (FFL) scanner.

Magnetic particle imaging (MPI) is rapidly emerging as a biomedical imaging modality with a diverse range of applications [1], including vascular imaging, cancer imaging, stem cell tracking, pulmonary perfusion imaging, and traumatic brain injury imaging [2]. As commercial MPI scanners become available, these existing applications open up MPI to preclinical and molecular imaging researchers. The unresolved challenges, on the other hand, make it an attractive area of research for an array of disciplines. This second issue of the fourth volume of the IJMPI presents 4 original research papers that address some of these challenges.

As custom-made and commercial MPI scanners are becoming more and more available in laboratory settings, there is a growing need for quality assurance phantoms that can help evaluate and compare the performances of these scanners. In [3], dedicated phantoms that can be used for such purposes in both MPI and MRI are presented. The proposed phantoms incorporate oleic acid coated magnetic nanoparticles (MNP) embedded in Permagel synthetic polymer as matrix material. Here, the oleic acid coating prevents agglomeration of the MNPs to preserve their MPI response over time. The matrix material, on the other hand, is a commercially available material that not only provides long term stability and fixation of the MNPs, but can also be used in conjunction with a variety of MNPs. MRI visibility of this matrix will facilitate co-registration of MPI images with morphological images from an MRI scanner.

In [4], a technique that enables multiresolution analysis for MPI is proposed. While discrete cosine transform (DCT) is a commonly used sparsifying transform for compressing the system matrix [5], it does not allow multiresolution analysis. The technique proposed in [4] achieves simultaneous system matrix compression and multiresolution image reconstruction via combining DCT and discrete wavelet transform. With this approach, MPI images can be reconstructed very rapidly at a coarse level, followed by a high resolution reconstruction if computational power and time are available. Future applications of this technique include compressed sensing based image reconstruction in MPI [6].

Thermometry is one of the fast emerging application areas of MPI [7, 8]. Today, temperature increases during high intensity focused ultrasound (HIFU) ablations are typically monitored via magnetic resonance imaging (MRI) thermometry, which can be costly and prone to motion artifacts [9]. In [10], an MPI compatible HIFU transducer is presented, achieving ablative acoustic intensities without interfering with the MPI signal. This important study confirms that MPI is a feasible alternative for thermometry during HIFU-induced hyperthermia treatment of tumors.

In [11], a novel field free line (FFL) scanner design is proposed. The spatial selectivity in MPI is typically achieved either via a field free point (FFP) or a FFL configuration. While it has been shown that the FFL configuration has the added advantage of increased sensitivity and/or reduced scan time [12, 13], building an FFL scanner that features a large bore can be quite challenging. To address this challenge, the design in [11] features two opposing Hallbach cylinders discretized by permanent magnets to generate a FFL with a strong gradient of 5 T/m, without power consumption. Rotation of the gantry, as done in computed tomography (CT), has the potential to enable rapid 2D imaging of upto 10 frames per second.

In summary, the articles in this issue provide a taste of some of the open problems in MPI, together with potential solutions. The novel techniques proposed will further guide the preclinical applications, as well as future clinical applications of MPI.

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