International Journal on Magnetic Particle Imaging
Vol 5, No 1-2, Article ID 2003002, 2 Pages

Infinite Science Publishing

Guest Editorial

Extending the Toolset for MPI Instrumentation and Reconstruction

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Received 19 March 2020; Accepted 20 March 2020; Published online 22 March 2020

Abstract

This issue of the fifth volume of the International Journal on Magnetic Particle Imaging (IJMPI) comes with four manuscripts, covering the topics of instrumentation, particle characterization, image reconstruction and standardization in the field of MPI. The manuscripts describe a novel and sensitive signal detector for magnetic fields, an open-source software package for data processing and reconstruction, a new kind of spectrometer for particle characterization, and a temporal polyrigid registration method for reconstructed MPI patches handling possible motion of large objects during imaging.

Since the first publication of Magnetic Particle Imaging (MPI) in 2005 by B. Gleich and J. Weizenecker [1], different scanner designs, multiple reconstruction approaches and novel ways of particle synthesizing have been presented [2]. One major goal of MPI is the operational usability in the everyday clinical practice in the near future. The feasibility for multiple applications, such as vascular imaging, cancer imaging, stem cell tracking, pulmonary perfusion imaging, and traumatic brain injury, could be shown on pre-clinical scale [3–7]. However, the transfer to human-scale applications requires several improvements in hardware design, image reconstruction and particle optimization.

In the first research paper of this issue of the fifth volume of the IJMPI, the authors describe a novel method for the detection of MPI signals [8]. Optically pumped atomic magnetometer (OPAM) detect the electron spin precession in alkali-metal atoms contained in a glass cell [9]. This allows reaching sensitivities in the subfemtotesla per root square hertz range [10], which is comparable to the sensitivity of superconducting quantum interference devices (SQUIDs) but without the cryogen cooling requirements. In combination with a gradiometric receive coil and a flux transformer (FT), the MPI signal is remotely detectable. This allows on the one hand the direct combination with low-field magnetic resonance imaging (MRI) technology [11] and on the other hand the usability of low-frequency MPI hardware minimizing the risks of specific absorption rate (SAR) and peripheral nerve stimulations (PNS) [12].

The second research paper is dedicated to a topic, which is quite important for a young technology: standardization. After publishing the open-source MPI data format [13], the authors describe in [14] an open-source software package for the high-level multi-purpose programming language Julia [15] providing an easy access for researchers to the wide field of reconstruction approaches and algorithms used in MPI [2]. The package is focused on system matrix reconstruction and can handle single-patch, multi-patch, and multi-contrast data (multi-color MPI) and implements matrix compression techniques for reconstruction acceleration, which is important for near real-time visualization.

Magnetic Particle Spectroscopy (MPS) is an important technology for the investigation and characterization of the behavior of superparamagnetic iron-oxide nanoparticles (SPIONs), which serve as tracer for MPI. Since an MPS device can be seen as a 0D MPI system [16], the parameters given by the spectra are often not sufficient to predict the performance within an MPI scanner. The third research paper within this volume [17] describes a novel 1D spectrometer providing multiple excitation coils to mimic magnetic fields occurring within MPI scanners. The Nanoparticle Characterization System (NCS) is able to create AC field free points, gradient fields and multi-frequency excitation fields providing a full range of characterization parameters of the particle system. These parameters can be used to optimize particle synthesis as well as image reconstruction.

In the fourth research paper [18], the authors present a solution for handling multiple drive-field patches during the acquisition of moving objects. To overcome SAR and PNS limitations [12], large field of views (FOV) have been scanned in multiple steps (patch-wise) using additional focus fields [19]. For image reconstruction, the patches have been stitched together to create an image of the entire FOV. Since the scanned areas have slightly different time stamps, a simple stitching is not applicable since it would lead to inconsistencies at patch boundaries. To solve this issue, the authors proposed a registration-based method to reconstruct a motion-compensated image, which relies on a polygrid transformation model of the underlying object motion ensuring temporal smoothness. With an optimized criterion for the simultaneous estimation of reconstructed image and underlying object motion, the system can be solved using an alternating optimization scheme.

In conclusion, with the novel signal detector, a standardized reconstruction framework, a novel spectrometer for faster optimization of particle synthesis, and a registration method for imaging large objects with possible motion, a few more steps have been taken on the way to clinical MPI in the near future.

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