International Journal on Magnetic Particle Imaging
Vol 3, No 2, Article ID 1803001, 3 Pages

Infinite Science Publishing

Editorial

Novel Field Sequences, Reconstruction Algorithms, and Particle Synthesis Approaches for Magnetic Particle Imaging

Tobias Knopp[a,b,*]

[a]Section for Biomedical Imaging, University Medical Center Hamburg-Eppendorf, Hamburg, Germany
[b]Institute for Biomedical Imaging, Hamburg University of Technology, Hamburg, Germany
[*]Corresponding author, email: t.knopp@uke.de

Received 10 March 2018; Accepted 15 March 2018; Published online 15 March 2018

Abstract

The second issue of the third volume of the International Journal on Magnetic Particle Imaging (IJMPI) includes 12 papers that were mostly presented in short form at the 7th International Workshop on Magnetic Particle Imaging. The papers cover the major MPI research areas imaging sequences, reconstruction algorithms, particle synthesis, and preclinical applications. In addition, this issue features a technical report on the open source software **SFView**, which allows for analyzing 1D, 2D, and 3D MPI system functions.

Magnetic particle imaging is a tomographic imaging method that allows to image the spatio-temporal distribution of magnetic nanoparticles [1]. MPI is free of ionizing radiation and in turn safe to use in human applications. One key applications for MPI is vascular imaging [2] because the vessel tree can be visualized at high temporal resolution with outstanding contrast. The second important application area is targeted imaging since the applied nanoparticles can be functionalized in such a way that they bind to specific targets such as cancer cells or inflammations.

The second issue of the third volume of the IJMPI follows the first issue [3] and contains 12 papers covering the major MPI research areas imaging sequences, reconstruction algorithms, particle synthesis, and preclinical applications.

In the field of particle synthesis, [4] discusses the synthesis and characterisation of superparamagnetic polylactic acid based polymers. The synthesis process is outlined in detail and first imaging results are presented. An entirely different approach is taken in [5], which discusses the fabrication of magnetic discs using lithography methods. Such particles potentially have a very low saturation field strength when materials like permalloy are used. For biological application, these particles need to be properly encapsulated. In [6] the authors utilize magnetosomes for the generation of highly monodisperse particles. The particles generate a magnetic particle spectroscopy signal which is one order of magnitude stronger than Resovist. This is a major step towards ultrasensitive MPI.

Medical applications are the focus of [7]. Using a liver tumor mouse model, the authors show that MPI can be used to detect large tumors whereas smaller lesions are not visible due to the low spatial resolution of the preclinical MPI system being used ($1.5\,\mathrm{Tm}^{-1}\mu_0^{-1}$). Liver imaging is a potential key application of MPI since most particle systems (e.g. with a dextran or carboxydextran coating) are uptaken by the Kupffer cells in the liver within minutes after intravenous injection. Sensitivity limits for *in* *vivo* measurements of molecular biomarker concentrations are investigated in [8].

In the field of imaging sequences the present IJMPI issue contains two publications both developed in the context of the traveling wave MPI (TWMPI) scanning principle. One practical issue of MPI is that the particle concentration will varies over various orders of magnitude. For instance the MPI signal generated in vessels will be much larger than that generated in perfused organs. However, the analog-digital-converter (ADC) has a limited input range such that either the strong signal is clipped or the weak signal is smaller than the quantization error. In [9] the authors propose to adapt the drive-field strength in order to increase the dynamic range of their TWMPI system. In phantom experiments it is shown that selective scanning with low and high drive-field strengths allows to resolve concentration differences in the order of factor 30. In [10] the authors develop a 3D dynamic rotational slice-scanning mode for TWMPI that enables near real-time imaging with 5 volumes per second for an imaging volume of size $65 \times 25 \times 25$ mm^3.

The MPI system function is investigated in [11], [12], and [13]. For quantitative MPI it is important that the particle concentration within the reference sample used for system calibration is taken into account during image reconstruction. In [11] different reference sample concentrations are evaluated and the resulting signal is found to be linear within the considered concentration range of 0.1 mmol(Fe)/L and 1 mmol(Fe)/L.

One further important area of research is the reduction of the system calibration time. This can be done by reducing the number of necessary calibration positions during the acquisition of the system function and the application compressed sensing techniques. In [12], the authors evaluated how these compressed sensing based system calibration techniques perform for different sampling trajectories.

Finally, in the technical report [13] an open source software for quick analysis of 1D–3D MPI system functions is introduced. The software **SFView** has a graphical user interface and is freely available under the GPL licence (v2). It allows to analyze system functions acquired with a preclinical MPI scanner from Bruker. In addition it is planned to support system functions stored in the magnetic particle imaging data format (MDF) [14].

MPI image reconstruction was investigated in [15] and [16]. The first work focuses on model uncertainties within the context of model-based image reconstruction. In the second work a low-latency real-time reconstruction framework was developed. In contrast to the real-time reconstruction framework developed in [17] the framework presented in [16] is tailored for TWMPI systems and can handle large image sizes up to 500×500 pixels.

In summary, the current issue of the IJMPI shows that MPI can still be improved in various aspects ranging from sensitivity over scanning efficiency to reconstruction algorithms. In combination this will open new medical applications in which MPI can show its potential to become a clinically relevant tool for diagnostic imaging.

References

[1] T. Knopp, N. Gdaniec, and M. Möddel. Magnetic particle imaging: From proof of principle to preclinical applications. *Physics in Medicine & Biology*, 62(14):R124, 2017. doi:10.1088/1361-6560/aa6c99. article.

[2] M. G. Kaul, T. Mummert, C. Jung, J. Salamon, A. P. Khandhar, R. M. Ferguson, S. J. Kemp, H. Ittrich, K. M. Krishnan, G. Adam, and T. Knopp. In vitro and in vivo comparison of a tailored magnetic particle imaging blood pool tracer with resovist. *Physics in Medicine & Biology*, 62(9):3454, 2017.

[3] L. Sefc. Recent progress in MPI imaging methodology, scanner instrumentation, and image reconstruction. *Intern. J. Magnetic Particle Imaging*, 1(3):1706000, 2017. doi:10.18416/ijmpi.2017.1706000.

[4] C. Jacobi, T. Friedrich, and K. Lüdtke-Buzug. Synthesis and characterisation of superparamagnetic polylactic acid based polymers. *Intern. J. Magnetic Particle Imaging*, 2(3):1710001, 2017. doi:10.18416/ijmpi.2017.1710001.

[5] P. A. Löthman, T. Janson, Y. Klein, A. R. Blaudszun, M. Ledwig, and L. Abelmann. Magnetic particle spectrometry of microfabricated magnetic particles. *Intern. J. Magnetic Particle Imaging*, 2(3):1707001, 2017. doi:10.18416/ijmpi.2017.1707001.

[6] D. Heinke, A. Kraupner, D. Eberbeck, D. Schmidt, P. Radon, R. Uebe, D. Schüler, and A. Briel. MPS and MRI efficacy of magnetosomes from wild-type and mutant bacterial strains. *Intern. J. Magnetic Particle Imaging*, 2(3):1706004, 2017. doi:10.18416/ijmpi.2017.1706004.

[7] J. Dieckhoff, M. G. Kaul, T. Mummert, C. Jung, J. Salamon, G. Adam, T. Knopp, D. Schwinge, and H. Ittrich. Magnetic particle imaging of liver tumors in small animal models. *Intern. J. Magnetic Particle Imaging*, 2(3):1707003, 2017. doi:10.18416/ijmpi.2017.1707003.

[8] J. B. Weaver, Y. Shi, D. B. Ness, H. Khurshid, and A. C. S. Samia. Sensitivity limits for in vivo elisa measurements of molecular biomarker concentrations. *Intern. J. Magnetic Particle Imaging*, 2 (3):1706003, 2017. doi:10.18416/ijmpi.2017.1706003.

[9] S. Herz, P. Vogel, T. Kampf, M. A. Rückert, V. C. Behr, and T. A. Bley. Selective signal suppression in traveling wave MPI: Focusing on areas with low concentration of magnetic particles. *Intern. J. Magnetic Particle Imaging*, 2(3):1709001, 2017. doi:10.18416/ijmpi.2017.1709001.

[10] P. Vogel, M. A. Rückert, P. Klauer, S. Herz, T. Kampf, T. Bley, and V. C. Behr. Real-time 3D dynamic rotating slice-scanning mode for traveling wave MPI. *Intern. J. Magnetic Particle Imaging*, 2(3):1706001, 2017. doi:10.18416/ijmpi.2017.1706001.

[11] O. Kosch, U. Heinen, L. Trahms, and F. Wiekhorst. Preparing system functions for quantitative MPI. *Intern. J. Magnetic Particle Imaging*, 2(3):1706002, 2017. doi:10.18416/ijmpi.2017.1706002.

[12] M. Maass, M. Ahlborg, A. Bakenecker, F. Katzberg, H. Phan, T. M. Buzug, and A. Mertins. A trajectory study for obtaining MPI system matrices in a compressed-sensing framework. *Intern. J. Magnetic Particle Imaging*, 2(3):1706005, 2017. doi:10.18416/ijmpi.2017.1706005.

[13] U. Heinen, A. Weber, J. Franke, H. Lehr, and O. Kosch. A versatile MPI system function viewer. *Intern. J. Magnetic Particle Imaging*, 2(3):1706006, 2017. doi:10.18416/ijmpi.2017.1706006.

[14] T. Knopp, T. Viereck, G. Bringout, M. Ahlborg, J. Rahmer, and M. Hofmann. MDF: Magnetic Particle Imaging Data Format. *ArXiv e-prints*, February 2016.

[15] T. Kluth and P. Maass. Model uncertainty in magnetic particle imaging: Nonlinear problem formulation and model-based

sparse reconstruction. *Intern. J. Magnetic Particle Imaging*, 2(3): 1707004, 2017. doi:10.18416/ijmpi.2017.1707004.

[16] P. Vogel, S. Herz, T. Kampf, M. A. Rčkert, T. A. Bley, and V. C. Behr. Low latency real-time reconstruction for MPI systems. *Intern. J. Magnetic Particle Imaging*, 2(3):1707002, 2017. doi:10.18416/ijmpi.2017.1707002.

[17] T. Knopp and M. Hofmann. Online reconstruction of 3D magnetic particle imaging data. *Physics in Medicine & Biology*, 61(11):N257, 2016.

